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The Perminvars, a Group of New Magnetic Alloys

By G. W. ELMEN
Research Department

WHEN iron, nickel and cobalt are melted together in certain proportions, and the resultant alloys are suitably heat treated, their magnetic properties are unusual and fundamentally different from those of other magnetic substances. These unusual properties are found at low and medium magnetizations, but as the alloys approach saturation the magnetic properties gradually become similar to those of other substances.

Development of alloys with these properties resulted from the discovery in these Laboratories that cobalt affected one of the permalloys in an unusual manner. We were at that time investigating the magnetic properties of a series of permalloys in which a few per cent of a third metal was added to the nickel and iron. One of these alloys contained cobalt. Magnetic measurements indicated that up to moderate field strengths the permeability of this nickel-iron-cobalt alloy was constant to a remarkable degree. The constancy was materially better than for soft iron, notwithstanding the fact that the initial permeability was several times higher. This was unusual, as small permeability-variation ordinarily is found only in materials with low permeability. Measurements of other magnetic properties were equally surprising. When the hysteresis loop was traced for a cycle which carried the flux density up to a few thousand gauss, it was found to have an extraordinary form in that it was sharply constricted in the middle. These and other differences indicated that in this alloy we had discovered a distinctly new type of magnetic material.

This discovery aroused a great deal of interest for it was recognized that a magnetic material possessing these properties was of great scientific and technical importance. In order to develop the possibilities which this alloy suggested, an exploration of the whole field of the iron-nickel-cobalt

A more detailed description of the alloys investigated and their magnetic properties will be found in the September issue of the JOURNAL OF THE FRANKLIN INSTITUTE.

series was undertaken. It was, of course, apparent that the alloy which had aroused our interest must be one of a group of compositions which possessed similar properties in a greater or less degree.

In this survey, alloys varying in ten per cent steps in composition and including the whole range of the ternary series of these metals were made up and their magnetic properties were tested. Approximately one-third of these alloys shared in such unusual magnetic properties. From this group a few were selected which appeared to be specially suited for magnetic uses in electrical communication circuits. An interesting example is the composition forty-five per cent nickel, twenty-five per cent cobalt and thirty per cent iron, which has in addition to the unusual magnetic properties a fairly high initial permeability.

Production of these alloys has as yet been in limited quantities. For the survey, alloys were cast in two-

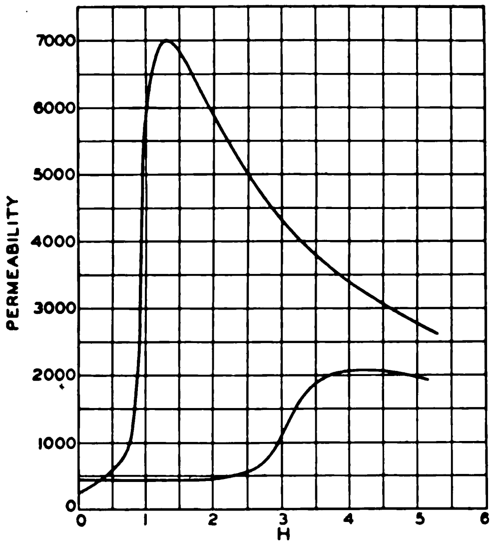


Fig. 1—Permeability curves for Armco iron (above) and for one of the perminvars (below)

pound ingots and mechanically reduced into 0.125 inch x 0.006 inch tape by J. H. White. A considerable number of larger lots of some of the

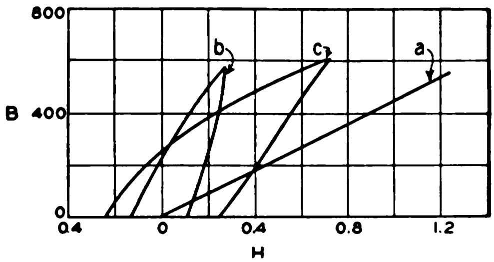


Fig. 2—Upper halves of hysteresis loops: (a) perminvar, (b) silicon steel, (c) Armco iron

compositions have also been made by him. One of the compositions has also been made on a small commercial scale by the Hawthorne Works of the Western Electric Company. Our experience with these alloys has been that when good grades of commercial materials are used, the castings are readily reduced mechanically to the desired dimensions, and the magnetic properties from the different castings of the same compositions are quite uniform.

We felt that these alloys were so unique as regards magnetic quality that they should be grouped in a class under a common name which should readily distinguish them from other materials. From the large number of suggestions "perminvar," a name proposed by V. E. Legg, was selected as the most suitable. This name is a combination of the first parts of "permeability" and "invariable," and therefore recalls one of the unusual characteristics of these alloys.

The perminvar properties are developed by heat treatment. The alloys are heated at 1000° C for a short time and then cooled. The rate of

cooling from 600° C to 400° C determines the degree to which these properties are developed. The best results are obtained when the rate is such that it takes about five hours to cool through this temperature range. With faster cooling the perminvar properties are less marked, and they disappear altogether when the cooling is so rapid that it takes only a few seconds to cool through the critical range. Above 600° and below 400° any convenient rate may be used; but it must not be so rapid that strains are set up in the alloys.*

Measurements for the composition forty-five per cent nickel, twenty-five per cent cobalt and thirty per cent iron specially heat treated are plotted in the figures. The curves in Fig. 1 illustrate the permeability characteristics for this composition and in addition for a sample of annealed Armco iron. For magnetizing forces below 1.7 gauss, the permeability is substantially constant, the variation being less than one per cent. This constancy is remarkable for a magnetic material having an initial permeability approaching 500 and therefore nearly double that of iron. Within the same range of field strengths the permeability of the iron sample rises from an initial value of 250 through a maximum of 7,000 at a magnetizing force of 1.3 gauss and decreases to 6,000.

Another property of perminvar closely related to the constancy of permeability is the extremely small hysteresis loss in the range of magnetizing forces and flux densities in which the permeability is constant. This is illustrated in Fig. 2 where line *a* represents the plot of the upper half of the hysteresis loop for a maximum flux density of approximately 600 gauss. Curves *b* and *c* are similar plots for silicon steel and Armco iron. While the hysteresis loops for Armco iron and silicon steel have considerable areas amounting to thirty-three and fourteen ergs per cubic centimeter per cycle respectively, there is no measurable area for the perminvar alloy. Although the ballistic method of measurement, which was used in obtaining these curves,

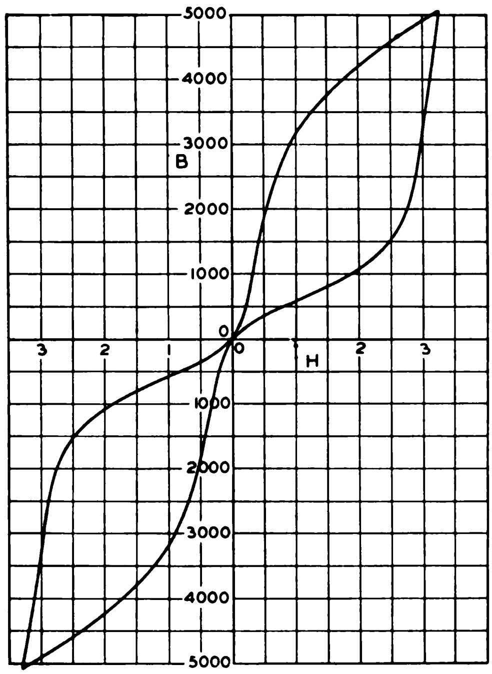


Fig. 3—Complete hysteresis loop for one of the perminvars. Note its constriction at the zero point

does not readily indicate very small losses, it is evident that the losses in the perminvar alloy are of a different order of magnitude from those of the other two materials. With more sensitive methods it was found that the hysteresis loss at a flux density of

* *Heat treatments and magnetic measurements in the development of these alloys were carried out by G. A. Kelsall and those associated with him in investigating magnetic materials.*

100 gauss was .024 x 10^{-3} ergs per cubic centimeter per cycle. In this regard, the best material previously known was permalloy, which under similar conditions had more than 1000 times this hysteresis loss.

These alloys are of special interest as magnetic core materials for apparatus used in the telephone plant where the magnetizing forces do not exceed the limits of constancy of permeability. The data apply to perminvar in the form of rolled sheet-metal; however the availability of the perminvar alloys in the form of highly compressed powder extends further than the probable field of application of these alloys.

Tests on experimental coils with perminvar cores have shown that some of the improvements in transmission quality predicted from the magnetic characteristics are realized. Among these improvements is a reduction in the "flutter" of transmitted speech caused by simultaneous telegraph operation. Modulation between currents of various frequencies in coils with perminvar cores is also greatly reduced as compared with coils having cores of other magnetic materials. Preliminary tests have indicated that perminvar alloys should be very efficient for continuous loading of telephone conductors. It would thus appear that perminvar may take its place beside permalloy as a magnetic material of fundamental importance in electrical communication.

To Build More Telephones

Stock with a par value of $185,000,000 *was subscribed in* 265,000 *applications received during the recent offer by the American Telephone and Telegraph Company. This left unused less than half of one per cent of the rights offered the stockholders. It is interesting to compare this figure with that of the* 1926 *stock offering in which over one per cent of the rights were unused. Eighty-four per cent of the new stock was paid for outright on or prior to August first, the closing date for subscriptions.*

Hunting Features in the Panel System

By E. L. ERWIN
Systems Development Department

HUNTING is the process of running over a group of trunks or lines all of which go to the same office or equipment and choosing for use the first one that is not busy. It is the second of the two types of selective processes that underlie all methods of telephone switching. The other, distinctly different, is a sort of intellectual effort which selects a group of trunks with a single action. In the panel system the first type of selection is performed by the sender with a translator or decoder;* the second type is performed by various forms of hunting circuits.

In a manual exchange the two processes may be seen in their simplest form. Suppose, for instance, that a subscriber calls a large department store located in an area served by another central office. On receiving the number wanted the originating operator by an act of memory locates the group of trunks running to that particular office. This is the first type of selective process. For it the operator must know the position on the board in front of her of the trunks running to the office called. Having located the desired group of trunks she runs along them, testing each with the tip of her plug, till she finds one that is not busy and plugs into it. Busy trunks have their sleeves grounded, and as the tip of her plug touches the sleeve of each trunk a click occurs in her head-set if the trunk is busy. The absence of a click indicates that her plug is at an idle line and immediately she connects into it. This is the hunting feature. It is a continuous process, as the operator's hand moves from one trunk to another in order until she finds one that is not being used.

At the called office the two processes are repeated. The second operator answers the call on her incoming trunk, receives the number from the first operator, and then, by

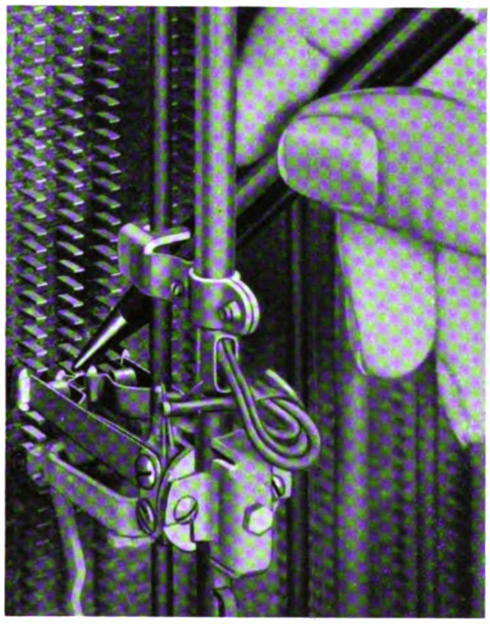


Fig. 1—Hunting with panel-type selectors is done by the brushes shown which are moved up in contact with the lugs by a drive below the field of the camera.

* BELL LABORATORIES RECORD, *Nov.*, 1926, *pp.* 77-81, *and May*, 1928, *pp.* 273-277.

memory, locates the group of lines running to the department store wanted. Following this she runs the tip of her plug over these lines till she finds the first idle one. This procedure is, again, the successive testing or hunting process.

Although finding an idle trunk or line is the most common use of the hunting feature it has been developed in the panel type of dial system also for the line-finders, used for finding and connecting to a line on which a call is coming in, and for the sender-selectors used to choose an idle sender. The sender apparatus is required for only a small fraction of the calling time and so, as the equipment is expensive, it has been found economical to provide but a small number of senders for a large number of lines. This requires a sender-selector to choose and connect to the first of the group of senders not in use as each call comes in.

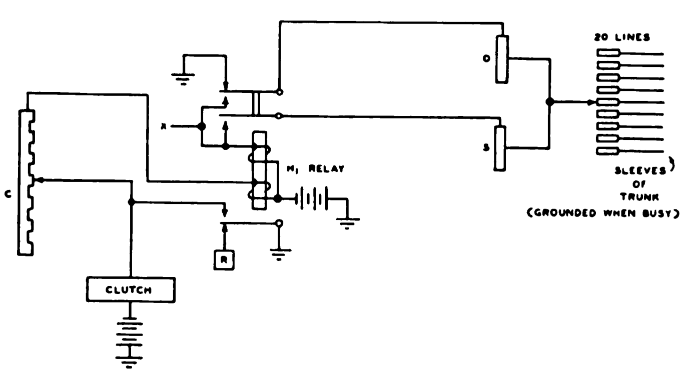


Fig. 2—Trunk selectors use one of the simpler forms of hunting circuits requiring only one relay and three contacts.

Hunting circuits and equipment vary somewhat with the class of work they perform but regardless of use there are always two things that they must accomplish. First, the hunting contact or brush, playing the part of the operator's plug carried from jack to jack by her hand, must have the power to move over a group of stationary contacts connected to the trunks or lines, as the case may be; and second, simulating the coordination between the operator's ear and her hand, it must be able to recognize an idle line and stop at it.

On panel-type selectors the multiple of the outgoing trunks terminates in small rectangular projections in the bank which may be seen in Figure 1. The movable brushes travel upward with all brushes in contact with the bank terminals. A clutch engaging with a continuously rotating cork roller at the bottom of the panel is the means of controlling the upward travel. In every case the upward motion is started by some action arising outside of the hunting circuits themselves. The action, however, generally uses one of the hunting relays, and the connection through which this starting is brought about is marked by an "x" on the diagrams.

The motion of the brushes of the selector is maintained, or stopped when an idle trunk is reached, by a contact on the hunting relay as may be seen through a study of the circuit diagram shown as Figure 2. The center row of terminals of the outgoing trunks is shown at the right of this diagram and the arrow on the connection coming up to them from the left indicates the moving brush. The upward mo-

tion is started by a connection of ground to "x," which operates the hunting relay (H_1) and energizes the clutch through the bottom contact. The hunting relay is held closed by a current flowing, through the two upper contacts in parallel, to the brushes and outgoing trunks which are grounded when they are in use. As long as the brush is in contact with a grounded terminal, therefore, it continues upward, but when an idle, or ungrounded, terminal is reached the hunting relay releases, and by so doing releases the clutch, and puts a "busy" ground on the trunk through the normal connection of the top contact.

Two features in addition to the two fundamental ones already mentioned are often included in hunting circuits: a centering device and the overflow terminal. To insure proper contact of all brushes with their corresponding lugs of the outgoing trunk it is necessary that the brushes be in line with about the center of the lugs. To accomplish this the rod that carries the brushes up along the bank terminals is equipped with the equivalent of a ratchet, and a small pawl drops into place to prevent it from falling back for each centered position of the brushes. If the hunting relay released very quickly, however, the brush might not be quite up to the centered position, so that the pawl would not be in the holding position and the brush would drop back one terminal and land on a busy line. The centering commutator (C), however, insures that the motor continues till the brush is centered on the lug. This commutator has a series of conducting and insulating segments (indicated on the diagram by depressions) and the whole is so mounted that the insulated segment breaks the contact at the proper time to center the brush on the lug. When the commutator brush is on a conducting segment it will be noticed that the hunting relay will be held operated even though the brush spring is on an idle trunk. After an idle trunk is found, therefore, the up motion continues till an insulating segment on the centering commutator is opposite its brush and this insures the centering of all the brush springs on their corresponding bank terminals.

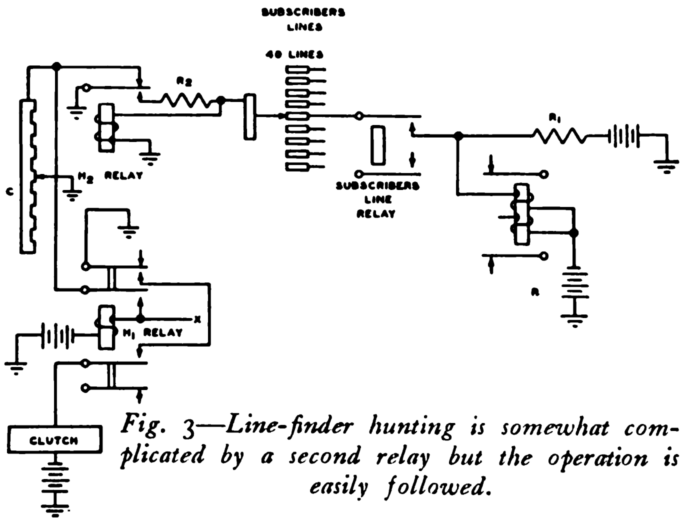


Fig. 3—Line-finder hunting is somewhat complicated by a second relay but the operation is easily followed.

The overflow-terminal feature provides against the possibility of an elevator hunting by the top of a group in which all the trunks are busy. The top lug of the group is not a trunk but merely an ungrounded, blank connection. When this lug is reached the hunting relay releases, and to prevent the top blank lug from being ground-

ed an insulated segment is placed on the overflow commutator (O) in a position corresponding to the overflow terminal. When this top lug is reached, therefore, the hunting relay releases, thereby stopping the motion of the brush, and the top terminal is kept ungrounded by the insulating segment on the overflow commutator so that other brushes arriving at this top level may likewise be stopped.

In the hunting circuit for the panel-type line-finders, Figure 3, similar fundamental features may be found although many of the details are different. Here the brushes run over a group of idle lines till the one is reached that is placing a call, and then connection is made to that one. This calling line has battery through a resistance connected to the hunting terminal in the bank. Two relays are used; one (H_1) is brought in to start the hunting motion and is held operated by a back contact on the other, or hunting relay, which is brought in by the battery on the calling line. A centering commutator is used here also and holds H_1 operated till the brush is properly centered.

For the sender-selectors different types of hunting circuits and switches have been used. The circuit shown as Figure 4 uses a rotary switch of the 200 type which is moved around step by step from one contact to another by a magnet shown at the left. The circuit arrangement is similar to that of the trunk selector. The hunting relay is brought in by a ground connection on the "x" lead and, on closing, operates the magnet through one contact and through another holds itself closed by the ground on busy sender-circuits. When an idle sender is reached the relay releases and grounds the hunt lead through a back contact to hold it busy. No centering device is necessary as the operating magnet moves the brushes just one full step each time. Also no overflow provision is required as, after passing over the semi-circle of twenty-two contacts,

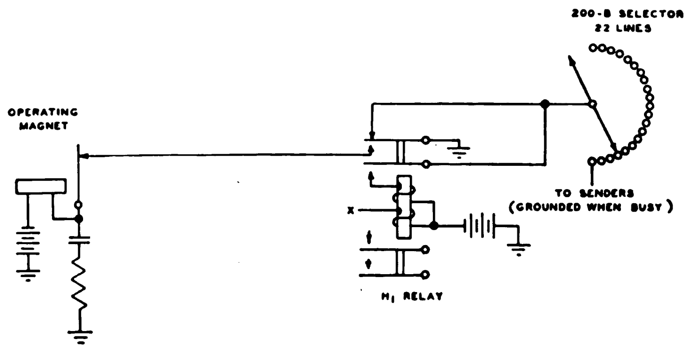


Fig. 4—Sender-selectors in their first forms attained a maximum of simplicity.

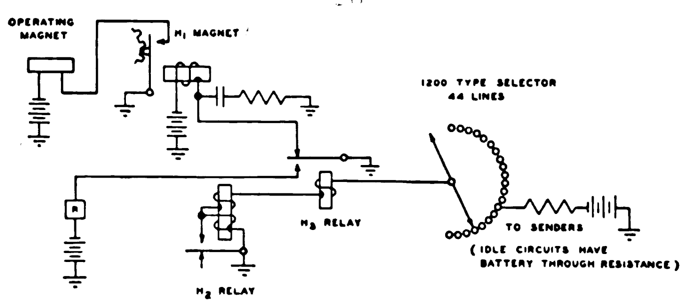


Fig. 5—The 1200 type sender-selector was complicated by the addition of a double test and requires in all two relays and two magnets but the circuit is readily traced.

the switch completes the circle and continues until an idle sender is found.

An improvement on this circuit is shown in Figure 5. Here also a rotary switch is used but it is of the 1200 type and the rotation is continuous instead of step-by-step. A close-up view of this switch showing the contacts, which are similar to those of the 200 switch, is given in the accompanying illustration. A centering device is incorporated in the magnet H_1. When an idle sender is found and the H_3 relay operates, the connection to H_1 is broken. The contact controlling the driving disk can not open, however, unless the lug on the back of it is opposite one of the depressions in the notched rim which rotates with the switch. The lug and notches line up when the brushes are centered on the bank terminals. This circuit also requires no overflow provision as the selector continues to rotate till an idle sender is found.

With the No. 200 type sender-selector arrangement, two selectors testing the same terminal at the same time would permit two calls to be connected to one sender. These double connections would occur most frequently during the busy hour, and would consequently interfere with service when it is most needed. This lack of protection against double connections led to the development of the rotary link with its double-test hunting scheme. With this when the brush first locates an idle sender sufficient current flows to operate H_2. As this operates it changes the circuit conditions by shorting out one of its own windings. With this change sufficient current would flow to operate H_3 and stop the turning motion, if in the meantime another selector had not landed on the same terminal and also operated its H_3 relay. In such a case neither selector would complete its operation but would continue to hunt, so that the chance of a double connection would be eliminated.

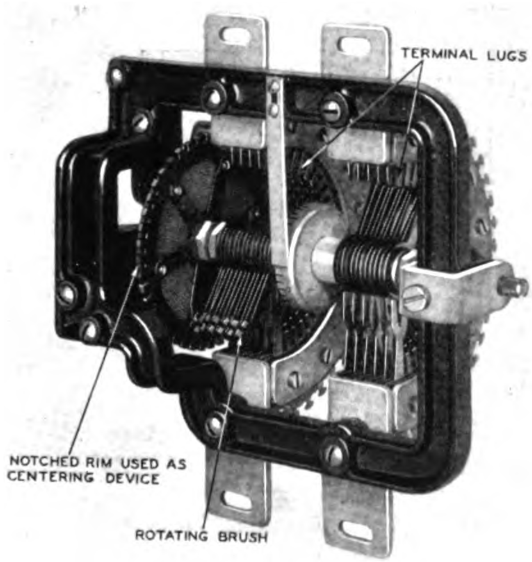


Fig. 6—*A close-up view of the* 1200 *type selector showing the brushes, contact lugs, and the notched rim used for centering.*

The latest type sender-selector is of the panel-link type. Like other panel-type hunting circuits it uses a centering device and the circuit is similar to that of the 1200 type, but with a superior type of double test.

In this circuit H_3 is operated to start the hunting travel and in turn operates H_1 which holds H_3 operated and energizes the drive magnet. There is a circuit through two coils

(A and B) of H_2 but as they are in opposition nothing results. When an idle sender is found, however, current flows through coil "B" and a third coil (C). These overpower "A" and cause H_2 to operate and close its contacts. This changes the circuit conditions by drawing a greater current through the opposing coil "A" and also draws a heavier current through "C" which is of low resistance. The closing of H_2 releases H_1 and would as a consequence release H_3 and complete the connection

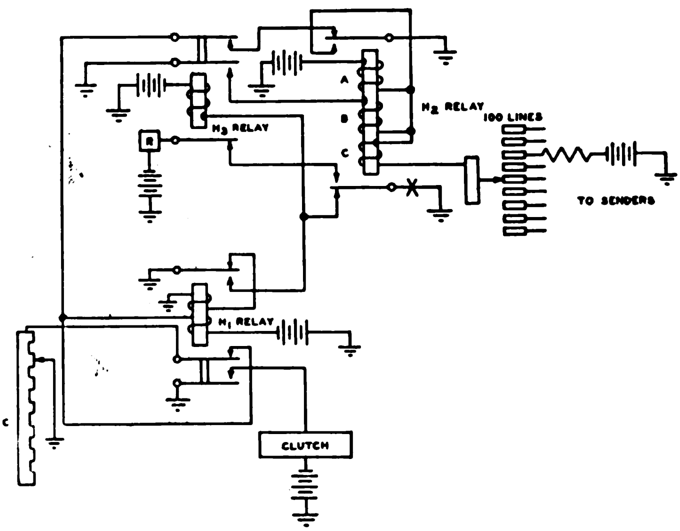


Fig. 7—A panel-link selector uses a more complicated circuit but the advantages gained are well worth while.

were H_3 not made slow releasing. With the changed condition in the circuit holding H_2 operated it would release again if another selector had in the meantime made contact on the multiple to this same sender and operated its H_2 relay also. If no other selector has made contact, or if one makes contact but its H_2 remains unoperated, H_3 releases after a few hundredths of a second and completes the circuit.

Hunting circuits for panel-type private branch exchanges are somewhat similar to the line-finder circuits and contain no features that cannot be understood from the preceding discussion. A centering commutator is used but no double test is felt necessary. A second test of the line similar to that of trunk hunting is made, however, after the sequence switch is advanced.

This summary of the hunting feature in the panel system gives a glimpse of typical panel circuits and mechanisms and shows how steps performed by operators in the manual system are here accomplished by relays and other electrical equipment connected in suitable circuits. The hunting feature itself is, of course, only a small part of the process of completing a call. It is set in action by other equipment making suitable connections to a point of the hunting circuit and when the desired line or trunk is found a third set of relays and circuits operates, the initial step often being through apparatus marked "R" in the circuits shown.

In all hunting circuits the operator's hand holding a plug should be visualized, rapidly passing over a row of jacks, touching each with the tip of the plug, and finally connecting to the first idle line. The circuits and relays indicated on the sketches are only substitutes for the motor nerves, ears, and intellect of the operator.

Cable Terminals

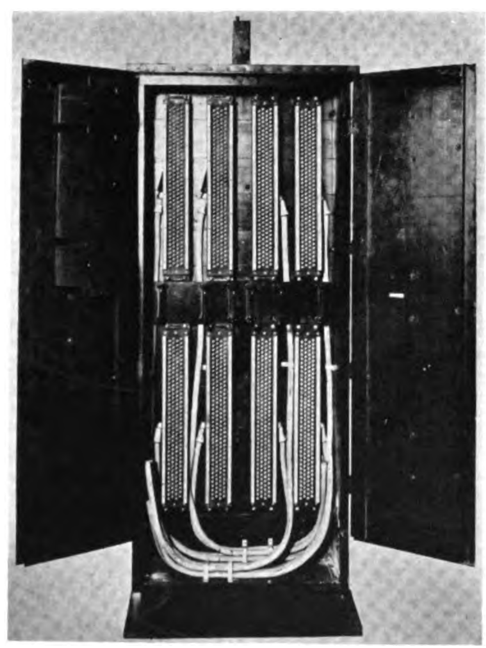
By A. W. DRING
Apparatus Development Department

TO join two or more aerial cables, the BB terminal is used where it is desired to have access to the conductors for testing and cross-connecting, and where fuse protection is not required. The BB terminal includes an outer wooden box, made of tongue-and-grooved lumber and thoroughly painted for protection against the weather, which may be fastened to the telephone pole. Within it are mounted "sealing chambers" of the binding-post type. The sealing chambers are long, narrow boxes of cast-iron with the cable entrance on one side. The panels which carry the binding post connections for the cable conductors are of hard rubber and cover the front of the chambers. Two fanning strips of hard wood are fastened the full length of each panel to faciliate the running of cross-connecting wires.

The boxes have single doors up to the 101 pair size and double doors for the larger sizes, up to 404 pairs. Space is provided at the bottom for splicing the stubs from the sealing chambers to the incoming cables.

The B cable terminal—a type which is now practically obsolete—is similar to the BB except that half of its sealing chamber capacity is designed for the attachment of fuses. This terminal was designed to form the junction between aerial and underground cable, the purpose of the fuses being to protect the central-office equipment in case the aerial section should accidentally come in contact with some electric light or power circuit. The B type terminal has been made in the same sizes as the BB.

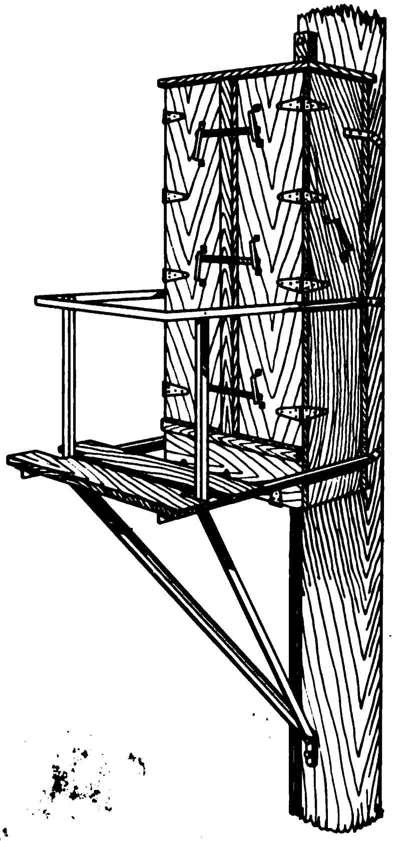
Where cables are to be connected to open wires, of considerable length however, some form of protection against lightning is required. This takes the form of protector blocks,



BB type terminal for 303-pair cables

the carbon faces of which are spaced a few thousandths of an inch apart. One block is grounded and the other is connected to the open-wire line,

The EA and EU terminals fill this need. They include boxes similar to the B type except that they are equipped with an inner and outer door to give better protection from the weather. They are now made only

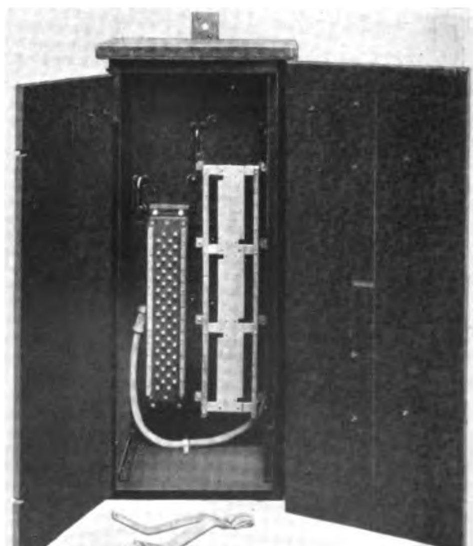


Sketch showing a balcony used with either B or BB type terminal

in twenty-six pair size. The difference between the EA and EU is the type of protection they afford. The former, which is the one illustrated in the accompanying photograph, has a binding-post chamber on the left side and on the right a supporting framework for mounting the open-space cut-outs. The latter differs from the EA only in that a fuse chamber replaces the binding-post chamber. The open-wire lines are connected to the protectors and the cable is spliced to the stub from the binding-post or fuse chamber.

To facilitate the making of connections at the B, BB, EA and EU terminals, a platform with guard rail is provided on which the workman can either sit or stand. These balconies, as they are called, are made in two sizes to fit the different terminals.

One of the recently developed terminals (the "C" type) takes advantage of many years experience and was designed to replace the old No. 8 and supplement the 14 type, described in the RECORD of last month. It follows very closely the style of the No. 8 but the supporting bracket and enclosing cover are rectangular instead of round. Also the entire sealing chamber is above and rests on the supporting bracket which gives the wooden parts better protection against weather. The wooden face panels are given a new finish that in-

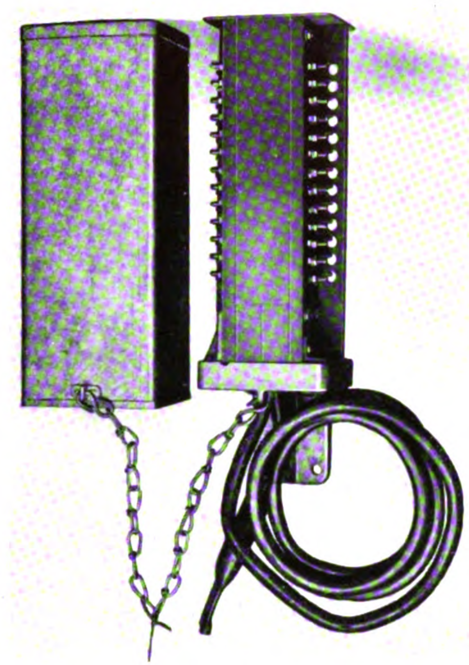


EA terminal, with the protector mounting on the right

sures a better insulation resistance. The drop wires enter at the bottom as with the No. 8 and pass through the supporting bracket between the fanning strip and the pole. Only three sizes, 10, 16 and 26 pair, are furnished as the class of service for which they are used seldom requires larger terminals.

Throughout this diverse line of cable terminals may be observed the same fundamental parts necessary for any terminals, which in one form or another have existed from the first. There is first a sealing chamber into which the end of the cable is run; second, some form of connector passing through the wall of the sealing chamber to which the ends of the cable conductors are fastened inside the chamber, and the outgoing wires on the outside; and third, the optional feature of electrical protection in the form required under the conditions. These three things are the fundamental elements of cable terminals and in their variety of treatment make the several different types.

Another important class, known as building terminals, is used inside buildings. These are made by outside suppliers under specifications prepared by the Laboratories. The terminals described in this article and



A 26-pair type C terminal, showing modifications from the older No. 8 type

in a preceding article by A. F. Gilson* are all for outdoor use and are of Western Electric manufacture.

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* Bell Laboratories Record, *July*, 1928, *pp.* 366-370.

The Grid-Current Modulator

By CLYDE R. KEITH
Research Department

CARRIER current communication* requires that the voice frequency currents from an ordinary telephone be changed to higher frequencies for transmission and then back to voice frequencies at the receiving terminal. Frequency bands above the voice range are used in order that the carrier frequencies may not overlap either the normal voice transmission range or other carrier frequency bands. It is then possible to transmit simultaneously several groups of high-frequency currents over a pair of wires without interfering with each other, and to separate the different groups at the receiving terminal.

To take a numerical example, if two currents of 1,000 and 10,000 cycles respectively are passed through a modulating device, many new frequencies will be produced, prominent among which are the first "sum" and "difference" frequencies, 11,000 and 9,000, respectively. Modulators as a class come in the category of circuit elements that do not obey Ohm's law. In ordinary metallic conductors, the current is proportional to the voltage, but in vacuum tubes, iron-core coils, certain crystals, and various forms of rectifiers, the relation does not hold. Figure 1 gives some examples of current-voltage curves which can be used for modulation.

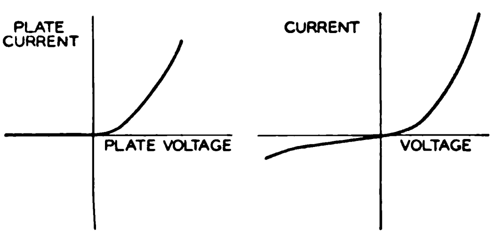


Fig. 1—Characteristic curves: left, that of the plate circuit of a vacuum tube; right, that of a rectifying crystal

One of the most usual modulators uses the non-linear relation between plate voltage and plate current in a three-electrode vacuum tube and is consequently called a plate-circuit modulator. Although the signal or carrier or both may be applied to the grid, modulation is made to take place primarily in the plate circuit by operating the tube so that the voltage induced in the plate circuit is substantially proportional to the applied voltage. This condition holds rather closely until the grid becomes positive with respect to the filament.

However, if the grid is allowed to become positive with respect to the filament, it is also possible to produce modulation by means of the non-linear relation between grid current and grid voltage. This method is therefore called grid-current modulation since it takes place only when conductive* grid current flows during

* *Multiplex Transmission by Carrier Currents, J. W. Horton,* BELL LABORATORIES RECORD, *Vol. 1, p. 147, December, 1925.*

* *This explanation neglects the current through the capacity between grid and filament since its effect is comparatively small at voice and carrier frequencies.*

at least a part of each cycle of input voltage. Since grid current can flow only when the grid is positive, as shown in Fig. 2, the relation between current and voltage is evidently non-linear for positive and negative voltages. Consequently, when carrier and signal voltages are applied, modulation between the two produces currents of sideband frequencies in the grid circuit. Voltages due to these currents are then amplified by the plate circuit and all other frequencies are suppressed by high impedances in the plate circuit. This allows all the power available in the plate circuit to go into sideband output, since none is used by the flow of carrier and signal currents as is the case with the plate-circuit modulator.

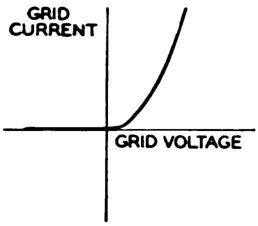


Fig. 2—Relation between grid current and grid-filament voltage

Our recent laboratory investigations have demonstrated that for certain applications, grid-current modulators have some important advantages.* They are particularly suited for use in circuits where high modulating efficiency and high output level are desired. When laboratory models of representative modulators are compared, it is found that (using the same tubes and plate voltages) the grid-current modulator gives a maximum power output eight times as high and a maximum plate power efficiency five times as high as the plate modulator. While this increased output requires sixty per cent higher plate current, a proportionately high output level may be obtained with a grid-current modulator when it uses the same plate current as the plate-circuit type. The carrier input current, although about twice that required for the plate modulator, can still be obtained from a single oscillator tube of the same type.

The operation of a grid current modulator may be most easily understood by referring to the circuit of Fig. 3 which represents the general form. It consists of sources of signal and carrier voltages in series with an external impedance and the grid-filament circuit of the tube. In series with the plate-filament circuit are simply a current-measuring instrument and an output impedance. Since the new frequencies which result from modulation are obviously not produced in the input generator or in the external impedance, they must be considered as having their origin in the variable impedance of the grid-filament portion of the circuit. Therefore the grid-filament path may be considered as a generator of "sideband" frequencies and of other modulation products.

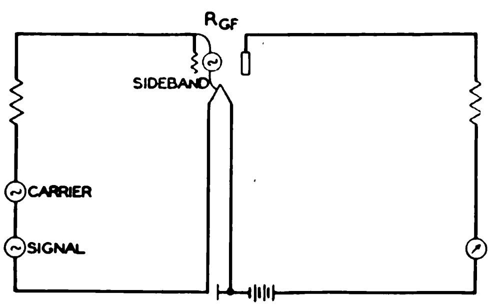


Fig. 3—General form of a modulator circuit

This generator has like all generators an internal resistance, sym-

* *Grid Current Modulation, E. Peterson and C. R. Keith,* BELL SYSTEM TECHNICAL JOURNAL, *January,* 1928.

bolized in Fig. 3 by R_{GF}, and, as is the case with ordinary generators, the terminal voltage—between grid and filament—is equal to the generated voltage minus the drop caused by the current through the internal resistance. The voltage drop in the generator is small when the external impedance is high so that little current flows. Consequently the grid-filament voltage at sideband frequencies is a maximum when the external impedance at these frequencies is large compared to the internal impedance. This is accomplished in practice by means of tuned circuits, retard coils, or filters, depending on the frequency of the sideband.

Since the sideband components generated within the grid-filament impedance of the tube result from the carrier and signal voltages impressed on this impedance, the sideband voltage will also be a maximum when the power inputs at these frequencies are a maximum. This may be calculated by the usual formulae for obtaining the maximum power from a source of current having a fixed impedance and voltage, and is found to occur when the external and internal impedances are properly "matched." Therefore the external impedance of the signal and carrier sources should be equal to the grid-filament impedance at these frequencies. These impedance relations for maximum sideband voltage on the grid are summarized in the adjoining table.

In this connection the question may be raised as to how one can assign a definite value to the grid-filament impedance when it varies throughout the cycle. By definition the impedance of a circuit element at a certain frequency is the quotient of voltage by current, both being at the stated frequency. Consequently in the steady state, with a fixed voltage of a particular frequency impressed, there must be a definite current component of this frequency which determines the impedance. The grid-filament impedance has been measured in actual circuits by means of a special bridge which does not affect the flow of current components other than the one at the frequency of the measurement. When using 101-D tubes under the usual operating conditions, the grid impedance at carrier frequencies amounts to a resistance of about 75,000 ohms.

Having obtained the maximum

Optimum Relation of External to Internal Impedances

Type of Modulation	Frequency	Impedances in Grid Circuit	Impedances in Plate Circuit
Grid Current	Signal	Match	External high compared with internal
	Carrier	Match	External high compared with internal
	Sideband	External high compared with internal	Match
Plate Current	Signal	Match	External low compared with internal
	Carrier	Match	External low compared with internal
	Sideband	External low compared with internal	Match

sideband voltage on the grid, it remains only to determine the impedance relations in the plate circuit for maximum power output at sideband frequencies. There are at the same time various other voltages on the grid which will produce currents of corresponding frequencies in the plate circuit depending on the external output impedances to these frequencies. If carrier and signal currents are allowed to flow in the plate circuit, they will modulate each other and so produce voltages of sideband frequencies which will combine with the voltages of the same frequencies produced by grid-current modulation. But it can be shown that the sideband voltages from these two sources are in opposite directions, so that their sum is less than the larger one alone. Therefore, since the sideband voltage induced in the plate circuit by grid current modulation is the larger, the maximum sideband output power is obtained when both carrier and signal currents in the plate-circuit are reduced to a minimum. This is accomplished by making the external output impedance high compared to the plate impedance at carrier and signal frequencies. However, the plate circuit should act as an amplifier to the sideband voltage developed on the grid by grid current modulation. Consequently the sideband power output is a maximum when the external output impedance matches the plate impedance at sideband frequencies. These optimum plate impedance conditions for a grid current modulator are obtained by means of transformers and filters, or, if the frequency separation is great enough, by tuned circuits.

In some cases it may be desirable to utilize plate-circuit modulation rather than grid-current modulation.

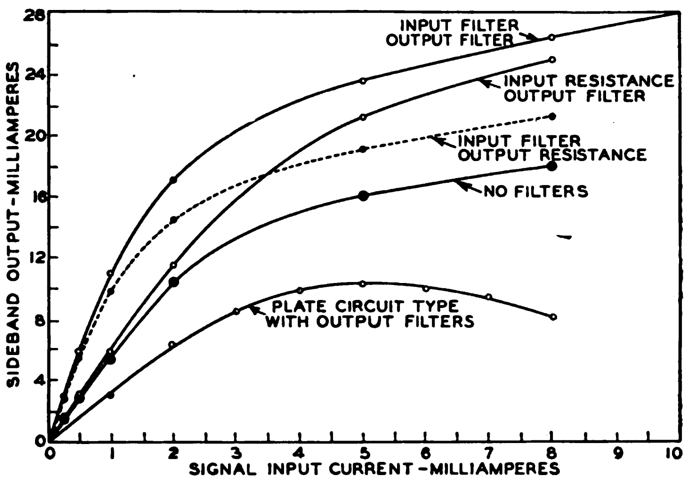
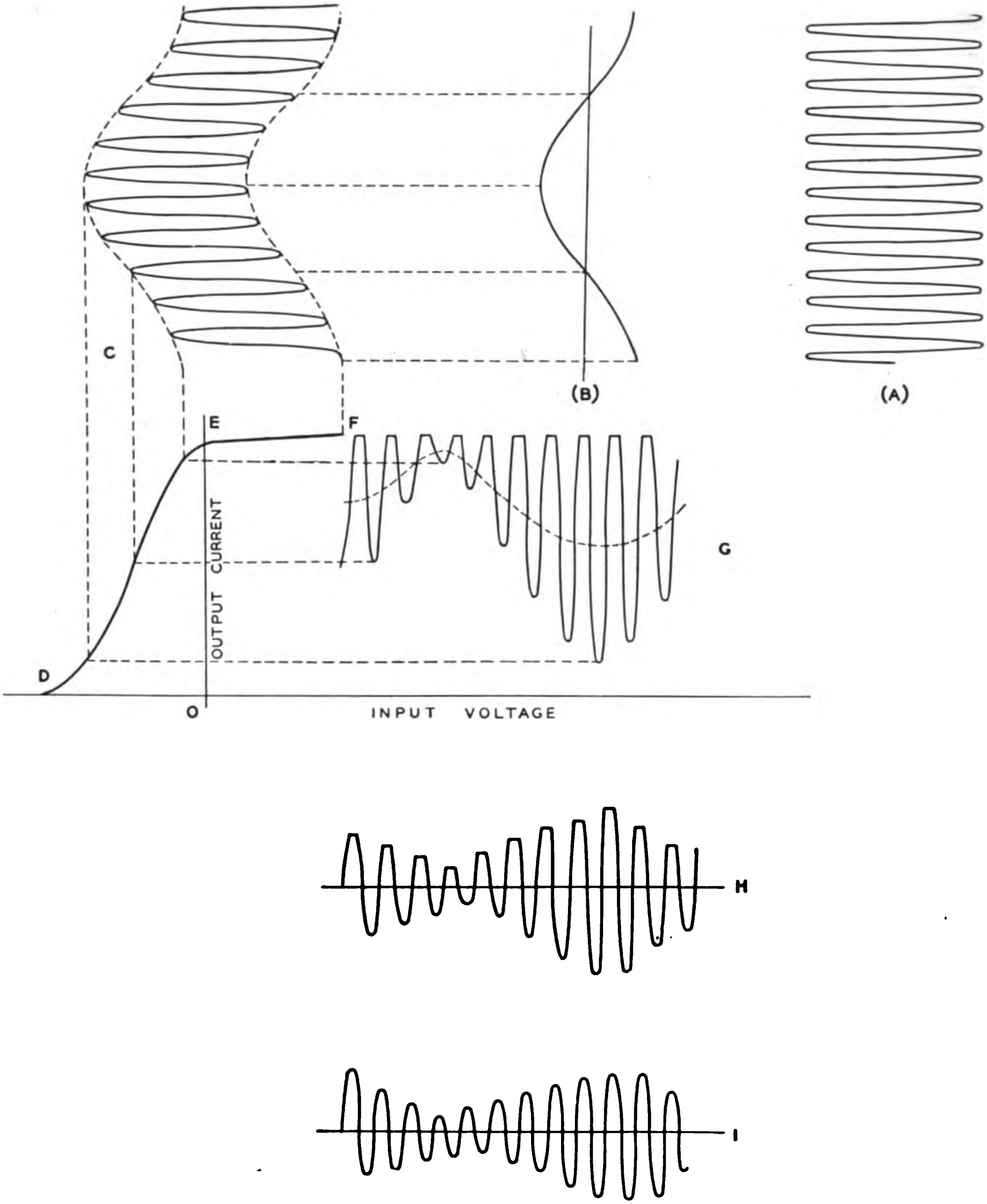


Fig. 4—Sideband output of a balanced grid-current modulator using 101-*D tubes*

The optimum impedance conditions may then be determined by the same line of reasoning as used above except that in this case grid modulation is made a minimum and plate modulation a maximum. These impedance conditions for the maximum plate modulation are listed for comparison in the table.

In both plate and grid circuits the optimum impedance conditions for maximum sideband output can often be met more easily with a balanced circuit than with a single tube. The general impedance relations are still the same as listed in the table but since part of the currents are balanced from both input and output circuits, the impedances to these frequencies



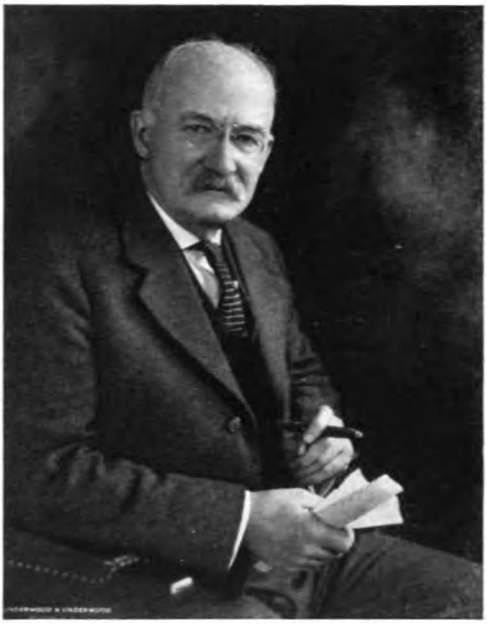
A graphic portrayal of how grid-current modulation takes place. A and B are carrier and signal currents, respectively, and C is the current which results from their flow through the ordinary "linear" conduction of the input circuit. DEF is the characteristic "non-linear" curve of a grid-current modulator. When the wave C is applied to this conductor its form is changed to that of G by the planing off of half of each wave. Since the mid-point of the new wave is itself a sine-wave, as shown by the dotted line in G, there remains in the new wave a component of the same frequency as the signal. Removing this component by means of a filter leaves the wave H. Sharp corners in this wave indicate that it contains components of still higher frequencies than the carrier (A). When these are removed, we have I, a modulated wave

may be provided by separate impedance units. Since the grid-current modulator was developed primarily with a view to its possible application to carrier telephone circuits, experimental work has been confined for the most part to balanced circuits in which the carrier is suppressed. Such a circuit is capable of giving an output of half a watt of single sideband when using 101-D tubes at 120 volts plate potential. Typical curves of single-sideband output are given in Fig. 4 showing how the output may be increased by using the proper filters in input and output circuits. The maximum plate power efficiency is then about fifteen per cent, as compared to about three per cent for a typical plate-circuit modulator. Listening tests have shown that these modulators will give about 10 TU greater sideband output than a typical plate-circuit modulator using the same tubes and plate battery with approximately the same distortion.

In the preceding discussion of the effect of external impedances on the output of a grid current modulator, no consideration was given to any frequencies other than signal, carrier, and sideband. However, the impedance to direct current has a considerable effect in the grid circuit. Since current can flow in only one direction through the grid-filament path, the voltage produced when it flows through an external resistance is unidirectional. This voltage creates a negative bias on the grid, which may become so high that the grid is positive with respect to the filament during only a very small portion of a cycle. It is during this portion of the cycle that modulation occurs, and so there results a considerable decrease in the output power available for large input voltages. Thus the external grid impedance should always be as low as possible to direct current.

The familiar grid-leak-and-condenser detector so universally used in radio receiving sets operates so far as the grid circuit is concerned very nearly in accordance with the above principles. In this case the external grid impedance consists of a resistance shunted by a condenser, giving a high impedance to voice frequencies but allowing the carrier and sideband input circuits to approximately match the grid in impedance. The grid leak also has a high resistance to direct current, which limits the maximum signal output just as has been explained in the previous paragraph. However, the external plate impedance is usually low compared to the plate resistance, instead of high compared to it, as shown in the table for optimum impedance conditions. This is due to other effects at the high frequencies and low amplitudes for which it is ordinarily used.

Tests made with carrier-frequency input to a detector tube have shown that a considerable increase in maximum output has been secured by replacing the grid leak with an inductance coil having a compartively low resistance to direct current. Under these conditions the fixed grid potential should be adjusted by a potentiometer to about that of the center point of the filament. Although this adjustment may vary to some extent with different tubes, it is not critical for large input voltages. The increased load-carrying capacity may be judged from the fact that with sufficient carrier frequency input an ordinary cone-type loud speaker may be operated from a balanced grid-current detector using two 101-D tubes.



Harry Bates Thayer

After nearly a half century of continuous service in the Bell System, Harry B. Thayer, Chairman of the American Telephone and Telegraph Company, has retired.

Entering the Western Electric Company in 1881, *Mr. Thayer became a Vice-President in* 1902 *and President in* 1908. *He was instrumental in the erection of our building at* 463 *West Street and had his office here for many years; the Engineering Department, which later became Bell Telephone Laboratories, was one unit of the organization which he headed. In* 1919 *Mr. Thayer became president of the American Telephone and Telegraph Company. When he resigned that office over three years ago to become Chairman it was with the idea, now accomplished, of gradually relinquishing his responsibilities to the Bell System interests he had served so faithfully and long.*

Insuring Central-Office Power Supply

By C. W. VAN DUYNE
Systems Development Department

FOR simplicity and reliability it would be difficult to better the power equipment used with the very first telephones installed. No battery or generator was required. The lungs and vocal cords of the persons conversing furnished all the power used for talking and pencil taps on the receiver diaphragm supplied the only power used for calling. No question of a reserve power supply could arise, for if the talker was there the power was too, as they, talker and power supply, were one and the same.

This primitive simplicity of power supply existed, however, for only a very short time; the carbon transmitter—so desirable for all lines except the very shortest—brought a need for direct current. As sources of power, various types of primary electric cells were first used. Then came the common-battery system with its storage battery, and dependence on central station electric power for recharging.

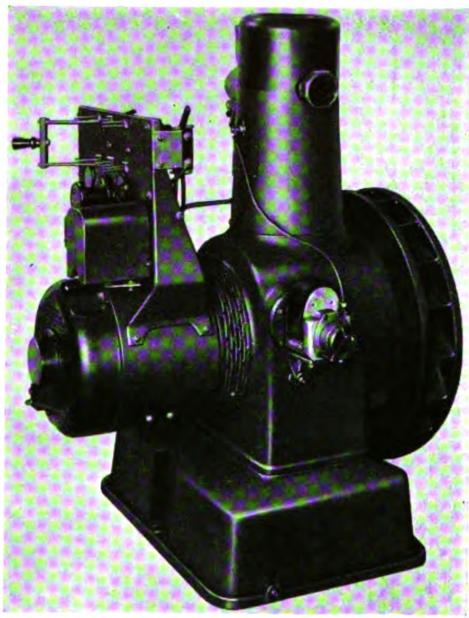
The storage battery for small offices is engineered to have a reserve capacity large enough for a day's service where suitable engine reserve is used. In the event of a failure of central station power of more than a day, reliance is placed on internal-combusion engines, permanently installed for the larger offices, and mounted on wheels for transportation to smaller offices as required. At different times and places various forms of internal combustion engines have been employed. Some used kerosene as fuel, others illuminating gas, and others, gasoline.

As time went by, it became evident that the benefits and economies usually realized from any standardization program were available in this field also. Accordingly it seemed desirable to survey completely the entire field of stand-by power units for central offices, and to standardize on a definite and small but adequate range of sizes to cover all demands at a minimum of overall costs and charges.

The entire range of sizes has been divided into three groups: the first covers only the smaller offices such as the Number 9; the second includes all the intermediate and large offices; and the third covers only those offices in very large cities where several central offices may be located in a single building. The developments finally selected to fill the intermediate group have already been described in the RECORD and the apparatus for the largest size offices will be discussed at a later date.

For the smaller offices three sizes of farm-lighting generator sets manufactured by the Westinghouse Electric and Manufacturing Company have been adopted. These have a single-cylinder, vertical, kerosene engine connected to a direct-current gen-

erator, and are manufactured in quantity production at low cost. A nation-wide service organization is available to facilitate the obtaining of replacement parts. The engine is of the four-cycle air-cooled type with



Generator end of a Westinghouse set. The flywheel, in the back, acts as a fan for cooling the engine.

high-tension magneto ignition and splash lubrication. The same engine is used for all three sizes but the generators are of different current and voltage ratings to suit the different types and sizes of batteries used. The smallest in current rating is 10 amperes at from 120 to 160 volts; the next is rated 25 amperes at from 22 to 65 volts; and the largest 45 amperes at from 22 to 33 volts. For the most part the standard Westinghouse set is used, but some special features have been added, as described below, to adapt the sets better to telephone applications and to increase the safety of operation.

The engines are equipped with governors which function to maintain the speed practically constant under variable load conditions. If the governor should become deranged, however, the characteristics of the engine are such that the speed might become dangerously high under light load conditions. To prevent this, a simple centrifugal overspeed trip has been developed. If the speed of the set reaches about 100 revolutions above the normal operating range due to governor failure, the centrifugal device functions to ground the ignition and stop the engine.

A crank case breather has also been developed for the engines furnished for use in the Bell System. The breather consists essentially of a ball check valve in a pipe, one end of which is connected to the crank case and the other to the air intake of the fuel-mixing valve. When the set is in normal operation the suction of the fuel-mixing valve at the top of the breather tube maintains a partial vacuum in the crank case, drawing into the engine cylinder any poisonous carbon monoxide gas which might be present in the crank case and preventing its escape to the engine room. Also, due to the reduced pressure in the crank case, oil leaks are prevented from the main engine bearings to the outside.

In telephone offices of the Number 11 type the 48 volt battery has a smaller current rating than the 24 volt battery and should be charged at a lower rate. For this reason and to permit charging different batteries in other applications a special control panel has been designed. It is mounted on the generator and carries a double-pole double-throw switch, am-

meter, voltmeter, voltmeter switch, fuse for generator overload protection, rheostat for controlling the battery charging rate, underload breaker to disconnect the generator from the battery in case of reverse current, and also a switch to start the engine by using the generator as a motor.

Equipped in this manner a light and compact unit is available for the smaller offices as may be seen from the accompanying photograph. It covers the requirements of a certain important group of central offices for standard units and does so at a notable saving in cost.

Variation in the Length of the Day

The observed change of rate of the earth's rotation consists of two parts, one a slow decrease in rate due to tidal friction and similar causes, and the other an irregular discontinuous change in rate, sometimes increasing and sometimes decreasing, of which the cause is as yet unknown. Due to the steady decrease in rate, the length of a day has increased, on the average, about 0.0025 *second per century during the last three centuries. The other variation is considerably larger, as well as irregular, but due to it the length of a day has never been observed to vary by more than* 0.0036 *second from the mean for the century. These figures are taken from "Nature" for January* 21, 1928.

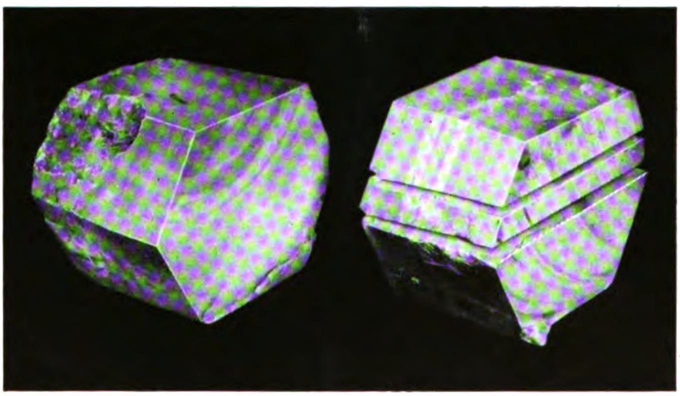
In an article, "Facts About Frequency Measurement" which appeared in the RECORD *for August, W. A. Marrison wrote, "But the astronomers tell us that at the present rate the length of a day will change about one second during ten years." At his request, the inaccuracy of that statement is being corrected by this note. There seems to be no need for alarm as to the inconstancy of the earth's rotation, at least as far as present methods of frequency measurements are concerned.*

Frequency Control for Broadcasting

By J. C. HERBER
Apparatus Development Department

EVER since the number of broadcasting stations in the United States increased to several hundred, the average listener-in has found at times that one or more of his favorite programs was ruined because of a high pitched whistle or tone received along with the program. Broadcast listeners are naturally interested to know the cause of this form of disturbance and the steps being taken to eliminate it.

The radio or carrier wave sent out by a broadcasting station is at a frequency between one-half and one and a half million cycles per second. The particular carrier frequency used by a broadcasting station is assigned by the Federal Radio Commission, and these assignments are 10,000 cycles apart. Thus one station may operate at 550,000 cycles, another at 560,000, a third at 570,000, and so on, up to one and a half million cycles. These frequencies of course can not be heard but serve merely, as the name indicates, to "carry" the broadcast program to the distant receiver. If two adjacent carrier waves are received by a radio receiver a beat frequency is produced as result of detection, which is equal to the difference between the carrier frequencies. This difference-frequency is 10,000 cycles if both stations are on their assigned frequencies. A 10,000 cycle note is not objectionable, since few radio receivers can amplify and fewer loud speakers reproduce this tone.



Natural quartz crystals, from one of which a slab has been cut

Theoretically, therefore, a 10,000 cycle interval between broadcast carriers should cause no interference at the radio receiver. Actually, however, it has been very difficult for broadcasting stations to maintain accurately the frequency of their transmitters and as a result instead of a 10,000 cycle beat note one of the order of 1,000 or 2,000 cycles is often present which may be of such intensity as to disrupt the program being received. This state of affairs has led the Federal Radio Commission to adopt strict regula-

tions regarding the departure allowed from the assigned carrier frequency.

To enable the broadcasting stations equipped with radio transmitters built by the Western Electric Company to meet the requirements of the Federal Commission and to maintain the frequency of these transmitters not only constant but correct to a high degree of accuracy a choice of two methods was possible. One is to supply very accurate frequency measuring apparatus; the other, which is the method adopted, exercises a direct control of the frequency by utilizing the piezo-electric properties of crystalline quartz or, as it is commonly known, "rock crystal."

Piezo-electric effect is a name given to the property certain crystals have of generating electrical charges on some of their surfaces when they are subjected to mechanical pressure. This process is reversible; that is, if an electric potential is applied to certain surfaces of the crystal, the crystal will mechanically distort itself and change its shape. Not only the whole crystal but a thin slab of it if cut in certain ways will exhibit the same characteristics. If alternating voltage is applied to the surface of such a slab it will expand and contract in perfect synchronism with the alternations of the applied voltage. This vibration of the crystal plate attains a noteworthy magnitude however, only if the frequency of the applied alternating voltage is the same as the natural period of mechanical vibration of the crystal. These interesting properties were not made use of until several years ago when the interdependent electrical and mechanical properties of the quartz plate were incorporated with the oscillating properties of the vacuum tube, the combination being known as the piezo-electric oscillator or more commonly, the quartz crystal oscillator, or "crystal oscillator."

Simply stated the operation of this device is as follows: Some of the electrical energy developed by the oscillator tube is used to "drive" the crystal. This causes the crystal to vibrate mechanically, generating

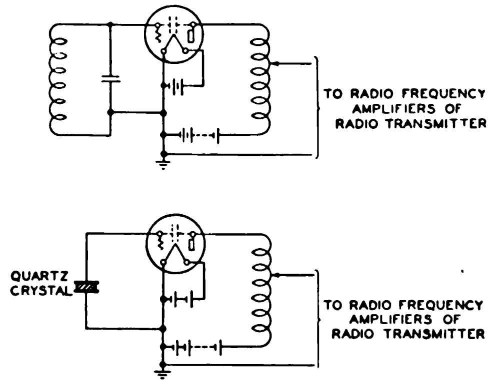


Fig. 1—*Schematic diagram showing the similarity between a tuned grid oscillator and a crystal-controlled oscillator*

charges on its surfaces which are fed back into the input circuit of the tube. Thus an electro-mechanical oscillator or generator of high-frequency currents is obtained in which the tube drives the crystal with the crystal determining the frequency at which the tube oscillates.

As actually used, the crystal plates are slabs or slices cut lengthwise out of the natural quartz crystal. These finished slabs themselves have come to be called "crystals." The photograph shows an uncut natural quartz crystal and another with a slab cut out of it which has been laid back in place to show how the cut is made. After a slab is cut out of the crystal proper its sides and ends are carefully ground so that they are very smooth and ac-

curately parallel to each other. The crystal plates in their finished form are approximately one and a quarter inches square. They are mounted between lapped metal plates and are connected as shown in the simplified schematic Figure 1, which also serves to show the analogy to an oscillator employing an electrical tuned circuit.

Thickness is the factor which determines the frequency of vibration; the thicker the crystal, the lower the frequency. A crystal for example having a natural period of 550,000

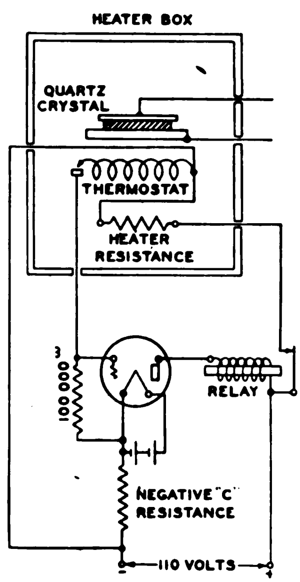


Fig. 2—Simplified diagram of the temperature control circuits

cycles per second is approximately 0.141 inch thick, while one which vibrates at 1,500,000 cycles per second is only 0.052 inch thick.

It was soon realized that even if great care was exercised it was practically impossible to grind the crystal as accurately as desired. This can be readily appreciated from the fact that a million-cycle crystal changes 100 cycles if only eight millionths of an inch in thickness are ground off. Another factor which also affects the crystal frequency is temperature and this property is made use of to accurately control the rate of vibration.

The coefficient of elasticity and the density, and therefore the natural period of vibration of the crystals, change with the temperature, as for any other mechanical object. The variation in their natural period of vibration with temperature may be either positive or negative, depending on the cut of the crystal, and varies in amount from about 30 to 80 cycles per million cycles per degree Centigrade change in temperature.

Thus a crystal may be ground to only approximately the correct thickness, and the desired frequency accurately obtained by controlling the temperature at which the crystal operates. Thus the ultimate fine control of frequency may be by temperature and not by grinding. In addition, by maintaining the crystal at a constant temperature, changes in frequency due to changes in room temperature are avoided.

To obtain temperature control of the crystal it is necessary to house it in a heat insulated box and to control the temperature of the interior by thermostatic means. The crystals are so ground that the frequency is correct at some temperature between 50° and 70° C. This is higher than any outside air temperature which is likely to be encountered anywhere, therefore some heat must always be supplied to the box to maintain the temperature at the proper point. The walls of these boxes are heavily lined with a heat insulating material. Inside of the chamber is mounted a pair of metal plates with the crystal between them, a heater unit, and an ad-



Front view of temperature control panel, with equipment for two crystals

justable thermostat which maintains the temperature of the crystal constant by opening and closing the heater circuit at such intervals that the total amount of heat supplied is just enough to maintain the box at the temperature for which the thermostat is adjusted.

The thermostat is so sensitive that it can not be used to open and close the heater current for the box directly. Instead the thermostat controls the operation of a vacuum tube, the tube in turn controlling a relay which opens and closes the heater circuit. A simplified circuit diagram is shown in Figure 2. When the temperature inside the box is less than that for which the thermostat is adjusted, the thermostat is open and the grid of the tube is connected to the filament through the 100,000 ohm resistance. A relatively high plate current is obtained under this condition which operates the relay, and current flows through the heater resistance supplying heat to the box. When the box has been heated to the temperature to which the thermostat has been adjusted the thermostat closes and connects the grid to the negative 110 volt connection which places a negative potential on the tube and decreases the plate current to a small value. The relay therefore releases, opening the heater circuit. As soon as the box cools a little the thermostat opens again and the process is repeated. The net result is that the heater circuit is opened and closed at short intervals (about once a minute) allowing the heater to give off a series of heat impulses which are smoothed out by the large metal lower plate on which the crystal rests.

By these means the crystal itself is kept at a very uniform temperature despite considerable variation in the surrounding room temperature. As a result the frequency of a radio transmitter, controlled by one of these crystals whose temperature is carefully regulated, should be at all times correct within a relatively few cycles. By maintaining the frequency with such accuracy, the beat notes produced by stations in different channels will be kept very close to 10,000 cycles. As has already been pointed out this frequency is well outside the range of audibility and so will never become a source of annoyance.

Work of Laboratories Involved in New Telegraph Company Contracts

PRESIDENT Walter S. Gifford of the American Telephone and Telegraph Company has just announced contracts with the Western Union Telegraph Company and Postal Telegraph-Cable Company that "will undoubtedly have a far-reaching effect on the development of electrical communications in the United States. In order to provide the best possible telephone service at the least cost, the American Telephone and Telegraph Company carries on continuous research and development and, as is well known, maintains a nation-wide network of telephone toll and long distance lines. Some of the developments of its Bell Telephone Laboratories have been incorporated in ocean telegraph cables, resulting in a large increase in capacity of words transmitted. Other developments and inventions of the Bell System can be utilized on telegraph lines, and also enable additional circuits required by telegraph companies to be superimposed on telephone toll and long distance lines. With the view to placing these developments at the service of the public, the American Telephone and Telegraph Company decided to make them available to telegraph companies and offered a series of non-exclusive contracts which have now been executed.

"Among them is one for the use of plant which should ultimately result in eliminating to a large extent the present duplication of parallel pole lines and wire circuits since, by the use of proper apparatus, it is possible to telephone and telegraph simultaneously over telephone toll and long distance wires. By this new arrangement many of the advantages that would accrue from the consolidation of all electrical communications will be obtained, and at the same time, the complete independence of the telephone and telegraph companies will be maintained.

"A contract has also been entered into by which the telegraph companies may lease the apparatus developed through Bell System researches and inventions so that under certain conditions several telegraph channels may be obtained from a single pair of telegraph wires.

"A further contract provides that the Telephone Company's telephoto system will be available to the Telegraph Companies' patrons for handling facsimile message service between the cities where the Telephone Company operates its system of sending pictures by wire."

The Rest Room in New Dress

By GRATIA L. PROUTY

Personnel Department

THE Women's Rest Room on the 11th floor is located in Section "B"—the oldest part of the building, dating back to 1896-97, and probably completed in its present form before 1900. The room was used originally for blue-printing by the manufacturing department before the days of blue-print machines. From two wide, low windows on the south, tracks ran out on the roof, on which the frames were pushed out into the sun.



The Rest Room as it appears from near the entrance

The room served a double purpose, however, for it also housed the photographic department. Portraits were taken in the favoring light from the north while the blue-prints were in making on the south.

After the war, when many departments were relocated, the room was released from its former uses, and turned into a rest room for the women. Rugs and big wicker chairs and curtains and cushions changed its aspect completely and made it a comfortable place in which to relax for a little while before the afternoon session. In 1921, the library subscribed to a few magazines for the room.

Out of hours the room has not been idle. Glee club and carol rehearsals have been held there and many a hard fought battle has been decided in the bridge tournaments.

Years of use left their mark on the furnishings, and soot and cinders did their part, till it was decided that the room needed a new dress, and J. G. Motley, Assistant Plant Manager, accordingly took the task in hand this spring. Since the sun pours in through so many windows it was decided to turn the place into a modern sun room. Colorful cretonne hangings, black woodwork and black wicker furniture with bright cushions against a light olive wall, a linoleum floor of cool red tile, and new parchment lampshades with a line of color make a Rest Room that is "decidedly different" and, judging by the increasing use, decidedly pleasing.

News Notes

DR. JEWETT addressed the Summer School for Engineering Teachers of the Society for the Promotion of Engineering Education at Pittsburgh on July 18, on the subject of engineering education and its relation to industry.

ON JULY 25, Dr. Jewett addressed the American Bar Association at Seattle on "Fifty Years of Science and Engineering."

Research

A. R. KEMP, P. A. LASSELL AND C. L. ERICKSON studied enamel wire manufacture at Hawthorne from July 15 to July 21. While there, Mr. Kemp also investigated problems in connection with submarine telephone cable.

J. E. HARRIS visited Hawthorne in connection with lead cable sheath development.

B. L. CLARKE spent several days in Norfolk, Virginia, inspecting tests in connection with cable corrosion.

A. L. JOHNSRUD lectured on television before the Department of Physics of the University of Minnesota on July 23.

W. G. BREIVOGEL visited Hawthorne in connection with work on handsets.

A. G. JENSEN, who has been engaged in work on transatlantic radio telephony in England, returned on July 16. Mr. Jensen plans to resume his work in England in September.

G. R. YENZER returned August 3 from a three weeks' stay in Hawthorne in connection with the manufacture of condenser transmitters.

HARVEY FLETCHER spoke on "Audition" before the S. P. E. E. Summer School at Cambridge, Massachusetts, on July 25.

J. B. KELLY addressed the summer session of Pennsylvania State College, his alma mater, on August 8. His subject was "Studies in Speech and Hearing with their Application to Social Welfare."

Inspection Engineering

D. S. BENDER has been appointed Field Engineer in the territory of the New Jersey Bell Telephone Company, replacing J. K. Erwin. Mr. Bender, in addition to assuming charge of the Field Engineering work in this territory, will continue as Field Engineer in the territories of the New England Telephone and Telegraph Company and The Southern New England Telephone Company.

A. M. ELLIOTT has been appointed Field Engineer in the territory of the New York Telephone Company, replacing J. K. Erwin in the Manhattan, Bronx-Westchester and Long Island Areas, and R. J. Nossaman in the Up-State Area. Mr. Nossaman will devote his entire attention to supervisory duties in connection with the Field Engineering Force.

J. K. ERWIN has been transferred to the Inspection Development Branch of the Engineer of Manufacture of Western Electric.

J. A. St. Clair has been appointed Field Engineer in the territory of the Pacific Telephone and Telegraph Company, replacing P. B. Almquist.

H. W. Newlund, Field Engineer at St. Louis, visited Fort Worth, Dallas, Denison and Oklahoma City during July in connection with his regular Field Engineering duties.

A. G. Dalton visited Chicago, Omaha, Denver, Los Angeles, San Francisco, Seatle and Cleveland during July and August in connection with Field Engineering work in these cities.

H. G. Eddy, T. Mellors and R. M. Moody attended regular Survey Conferences at Hawthorne during the first part of August.

A. N. Jeffries visited Hawthorne during the latter part of July in connection with audible motion picture work.

W. A. Boyd visited Omaha, Chicago, Indianapolis and Pittsburgh to investigate corrosion of telephone equipment and protective metal finishes.

Patent

J. G. Roberts visited Chicago in connection with the prosecution of patents. G. M. Campbell, G. H. Heydt and E. V. Griggs visited Washington for the same purpose.

Systems Development

E. W. Hancock visited step-by-step central offices at Hartford, Trenton, Reading, Altoona, Harrisburg and Scranton during July.

W. J. Lacerte is at Hartford, Connecticut, making tests on service observing equipment.

C. White visited the No. 3 toll boards at Cleveland, Ohio and Utica, New York.

E. P. Bancroft visited Montreal, Smith's Falls and Toronto, Canada, to confer with representatives of the Canadian Pacific Railroad Company on carrier telegraph installations.

H. M. Hagland and V. I. Cruser visited Philadelphia and Boston, respectively, to inspect new 551-A private branch exchanges.

J. G. Ferguson discussed private branch exchanges with Navy Department representatives in Washington.

D. C. Meyer visited Hawthorne and Cleveland during July.

J. H. Sole visited the General Electric Company plant at Pittsfield, Massachusetts from July 25 to 27.

G. A. Benson was in Des Moines, Iowa, for the purpose of discussing the proposed installation of pneumatic tube equipment in the new Des Moines Toll Office with engineers of the Northwestern Bell Telephone Company.

J. R. P. Goller visited the new repeater station power plants on the Washington-Atlanta cable at Greensboro, Durham, Norlina and Warrenton, North Carolina, and at McKenny, Virginia.

V. T. Callahan tested a new 150 horsepower gas engine at Memphis.

Outside Plant Development

J. M. Hardesty visited clay conduit manufacturing plants at Altman, Ohio, and Brazil, Indiana, and observed the manufacture and installation of concrete conduit in Chicago.

E. M. Honan was in New Haven on July 19 and 20 in connection with the field trial of drop wire attachments.

Apparatus Development

D. H. Newman has installed for the Life and Casualty Insurance Company of Nashville, Tennessee, the first of the new 105-C radio telephone broadcasting equipments. This equipment includes the crystal control

five-kilowatt transmitter. He has also completed the five-kilowatt installation of the University of Florida at Gainesville and visited Birmingham to discuss the technical features of the five-kilowatt station to be established there by the Alabama Polytechnic Institute. The Institute has for two years been operating a 106-A (one-kilowatt) equipment at Auburn, Alabama.

H. S. PRICE is supervising the installation of the fifty-kilowatt broadcasting equipment to be operated by the Crosley Radio Corporation near Cincinnati under the call letters WLW. An unusual feature is the proposal to install, in the same operating quarters, the five-kilowatt equipment of station WSAI and to continue operating the two stations simultaneously.

W. L. TIERNEY has completed the installation of a one-kilowatt broadcasting equipment for Louis Wasner, Inc., of Spokane and made the survey for the one-kilowatt station to be established by the Oregon State Agricultural College at Corvallis, Oregon.

V. F. BOHMAN observed the operation of step-by-step switches in New London, Connecticut on July 12 and 13.

F. J. REDMOND visited Hawthorne during the week of July 23 in connection with the development of a new dial number plate for use on coin collectors installed in telephone booths.

J. N. REYNOLDS AND J. F. HEARN visited the plant of the Precision Die-Casting Company at Syracuse on July 30.

J. R. TOWNSEND visited the United States Naval Academy at Annapolis on July 27 to discuss spring materials in connection with committee activities of the A. S. M. E. The following day he visited the Bureau of Standards in Washington in the matter of flatness measurements on condenser transmitter diaphragms.

R. V. TERRY spent three weeks in Hawthorne assisting in the production of the film recording machine.

GENERAL STAFF

R. W. KING addressed the Physics Section of the S. P. E. E. Summer School at Cambridge, Massachusetts, on "Physics as a Career in Industry."

W. F. JOHNSON was elected first vice-president of the Purchasing Agents Association of New York at the annual meeting of that organization.

Club Announcements for September

Golf

The Fall Golf Tournament will be held at the Salisbury Country Club, Salisbury Plains, Long Island on Saturday afternoon, September 22 and will consist of 18 holes of medal play. Players will be handicapped on the basis of scores turned in for previous tournaments, and after all entries have been received they will be divided into three classes. In each class there will be a prize for low gross score, and two for the low net scores. The entry fee is $2.00.

Course number five is reserved from 12 o'clock, and since another tournament is to follow ours it is important that the contestants start as soon as possible. At latest, players must report to the starter by 1:30.

Dance

The first dance of the 1928-29 season will be held on the roof of the Hotel McAlpin on Friday evening, November 2. With the attendance limited to 500, it is advisable to purchase tickets at once. They are $1.00 each. The dance will be under the direction of D. R. McCormack, who has managed the Club entertainments and dances for the last four years.

Women's Activities

The activities formerly conducted by Allegra Hamilton as Chairman of the Committee on Women's Interests of Bell Laboratories Club will, for the duration of the year 1928, be taken over by Natalie Skinner.

Bowling

The 1928-1929 season of the Bowling League will open Friday evening, September 26, at Dwyer's. Last year we engaged twenty-eight alleys, and this year an increased interest indicates that we may need thirty-two for the season, increasing the "D" group from four to eight teams. Those who have not yet indicated whether they want to bowl should do so at once, so that final arrangements may be made.

Baseball

The third baseball season of the Bell System Athletic League was completed July 31, when the Eastern Manhattan team of the New York Telephone Company, champions of the American League, won the post-season series from the Long Island Plant team, winners in the National League.

The final standing was as follows:

National League

	Won	*Lost*	*Tied*
N. Y. T. Co., Long Island Plant	6	0	
Bell Telephone Laboratories	5	1	
N. Y. T. Co., Long Island Traffic	4	2	
W. E. Co., Hudson Street	3	3	
W. E. Co., G. H. Q.	1	4	
W. E. Co., Installation	1	4	
N. Y. T. Co., Long Island C. & E.	0	5	

American League

	Won	*Lost*	*Tied*
N. Y. T. Co., Eastern Manhattan	6	0	
N. Y. T. Co., Central Commercial	4	1	
N. Y. T. Co., Building and Supply	3	2	1
A. T. & T. Co.	3	3	
N. Y. T. Co., Southern Manhattan	2	2	1
N. Y. T. Co., Central Manhattan	1	3	1
N. Y. T. Co., Western Manhattan	0	4	1

BELL LABORATORIES RECORD

AIRWAYS COMMUNICATION
By E. B. Craft

NOBEL LAUREATES
By K. K. Darrow

CRITICAL RELAYS
By W. Kuhn

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Record

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Bell Laboratories Record

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Airways Communication Service

By EDWARD B. CRAFT
Executive Vice-President

THE present development of air transport is bringing out its need for adequate communication in much the same manner as the earlier development of railway operations disclosed for that industry the necessity of special communication services if speed and density of traffic were to be attained with safety. The electric telegraph by a most fortunate coincidence was available just at the time the railways required it; and as the demand for speed became pressing the telephone was perfected. By another fortunate coincidence, radio appears to be available just at the time it is needed for communication with aircraft in flight. During the war, both in this country and abroad, radio equipment of relatively crude design was installed in aircraft and proved of great utility. Since the war, radio telegraphy for aircraft has been further developed by the naval and military services, but radio telephony has received less attention, probably because of the inherent difficulties and lack of a pressing demand.

When surprises due to bad weather can be eliminated, the safety of air transport should compare favorably with that of other forms of transportation. By means of a suitable communication system weather reports from observers located along and near an airway can be collected; and it should be possible, therefore, to reduce materially the weather hazard of air transport.

A full-scale meteorological experiment of this nature is now being conducted in California by the Weather Bureau with the cooperation of the Guggenheim Fund for the Promotion of Aeronautics and of the Pacific Telephone and Telegraph Company. Meteorologists at the Oakland and Los Angeles airports receive several times a day, by long-distance telephone, weather data from about forty observers at a large number of selected points in the state. After an exchange of these collected data, the meteorologists forecast flying-weather for aviators starting out over the air-

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This is an abridgment of an article contributed to Aviation for October 6, 1928.



Our flying laboratory ready to take off: A. R. Brooks is in his place as pilot and Mr. Craft is ready to talk when the plane gains altitude

way between the two airports. On the basis of these forecasts, it is hoped that the pilots may be able to avoid bad weather by choosing an alternative route or by selecting the terminal field where weather conditions are more propitious. The experiment will be carried on for a full year and so cover the complete cycle of the seasons. On the basis of the demonstrated value of this service to the users of the airway, the matter of its continuance or possible extension to other airways can then be decided by the Weather Bureau.

In addition to the problem of collecting weather data, there is the closely related matter of distributing local weather reports and forecasts between airports. This is "point-to-point service." It may be accomplished by a special radio-telegraph network, by commercial telegraph or by long-distance telephone, and over private or leased wires either by telephone or by telegraph. Local conditions, volume of traffic and economic considerations, in general, determine which of these types of service should be provided.

Besides its use for weather messages, point-to-point communication between landing fields along an airway is desirable for following the progress of an airplane with its passengers and cargo. Such a dispatching service is somewhat analogous to that of a railway and is a necessity if scheduled connections with trains and other aircraft are to be met. Point-to-point communication facilities are also required for the general adminis-

trative business of the airway and of the air transport companies.

On some airways communication between terminal landing fields or airports is now handled by radio telegraph and on others by long-distance telephone. Neither system is ideal for the purpose. An ideal system which is instantaneous and reliable, repeats messages at all airports, is free from interference, takes up no radio channels, and furnishes a permanent record of all messages at all airports, is the telephone-typewriter service. This makes possible the instantaneous transmission of communications between distant offices and simultaneously provides each office and any desired intermediate stations with typewritten copies. This service has been used for a good many years by the principal press associations and is now being extended rapidly to serve the needs of our larger business organizations.

To utilize the telephone-typewriter system along an airway requires only the installation of keyboard transmitting apparatus and tape printing apparatus at terminal fields and their interconnection by a private or leased wire circuit. Then anyone familiar with a typewriter may type a message which will appear on the tape fed automatically from the apparatus at every other connected point. The message is automatically and permanently recorded under the control of the sending station. Constant attendance or listening-in is, therefore, not required; and operators at the various receiving points are thus free to attend to telephone calls from intermediate fields, to operate radio beacons and lights, and to carry on whatever duties are assigned to them.

Telephone-typewriter service has been initiated by the Department of Commerce at Hadley Field, at Cleveland, at Chicago and at San Francisco, where in each place the local radio stations, weather bureau offices and the airport offices are all interconnected. It is planned, at a later date, to equip experimentally some airway with complete telephone-typewriter service between airports.

When an aviator leaves an airport he should be given information of the weather along the route ahead of him and a forecast of the nature of probable changes during the time of his flight. If general weather conditions are settled, or if his flight is a short one, a forecast is entirely adequate. However, for long flights and at times of uncertain and threatening weather, it is important that the pilot



Mr. Craft inspects the radio transmitter and receiver



Building and antenna system of the experimental station at Whippany, where one end of the plane-and-ground channel is located

be continuously advised by radio of the weather conditions he may encounter during his flight. In particular, storm warnings and reports of the visibility and landing conditions at the airport where he expects to land should be sent him. Weather and landing advice can be broadcast from each airport along the airway. Provision of radio transmitters at airports and receiving sets in the planes will make possible a simple one-way system of communication and permit any number of planes in the air to be advised without confusion.

The perfection of facilities for communicating weather and landing information to planes in flight, which will enable them to operate with safety under relatively unfavorable meteorological conditions, will greatly stimulate the demand for improved aids to navigation. It seems to be established that under conditions of poor visibility, when landmarks are totally obscured and beacon lights are useless, flying requires some form of radio goniometry if the pilot is to find his way through.

A number of systems have been proposed for this purpose; evolution of the system which is most satisfactory will be a matter of time and will require close cooperation on the part of all factors in the industry.

Bell Telephone Laboratories, at its radio station at Whippany, New Jersey, has erected an experimental two-way radio-telephone system and radio beacon. In connection with this apparatus it utilizes a Fairchild Cabin Monoplane with Pratt and Whitney "Wasp" engine. The plane has been carefully bonded and shielded and is equipped with radio field-measuring apparatus of the Laboratories' design. With this plane exact measurements can be made at various altitudes under different weather conditions of the efficiency of radio transmission from the Whippany transmitter. In addition the plane

carries radio transmitting and receiving sets of experimental design. It is, in fact, a flying radio laboratory in which the engineers may experiment under actual flying conditions.

A radio-telephone system with a sufficiently powerful transmitter and sufficiently sensitive receiver to give reliable communication for 100 miles will give fair communication for perhaps 200 miles, and its carrier wave will interfere with reception for a much greater distance. To avoid interference due to the beating of carrier frequencies, airports within a few hundred miles of one another may be assigned to different frequency channels, but serious difficulty is at once apparent from a map of the National Airways. Within 800 miles of Chicago, for example, there are over fifty terminal fields or airports. It would seem obviously impractical to assign the available telephone channels of which the international agreement allows six, to cover the eastern and central United States without serious interference. By restricting power as much as possible and by other means yet to be devised, it may be found possible to assign the same wave length to airports relatively nearer together. For the distribution of weather information only, however, the airways may well find insufficient the frequencies in the exclusive band, 315-350 kilocycles.

On certain main routes, air transport companies will eventually require two-way telephone despatching systems of their own to control plane movements. These systems will consist of radio stations situated at the various airports along the route and interconnected by suitable wire lines. The frequency channels required for such services cannot be found in the 315-350 kilocycles band which, as just indicated, is apparently inadequate for the public services of weather broadcasting from airports. Further channels in the short-wave region appear to be necessary.

In the short wave region Bell Telephone Laboratories have initiated an additional development project. In cooperation with the Boeing Air Transport Company, the Laboratories have undertaken to survey the Chicago-San Francisco Airway and to develop a system of two-way telephony between planes in flight and terminal landing fields on this route. The Boeing Company planes and landing fields will be equipped with experimental radio apparatus and a cooperative experiment will be conducted during the winter of 1928-29. From this work it is hoped to determine for an air transport company the requirements for a two-way radio telephone service. The investigation will furnish the basis for offering such facilities to other air transport operators.

In all these present and future problems, it is the policy of the American Telephone and Telegraph Company and the Bell System to assist by developing ways and means for making available to commercial aviation the best possible communication service.

The Nobel Laureates

By KARL K. DARROW
Research Department

RENOWN in art is still so controversial, opinions about art are influenced so much by feelings and emotions of deep and unknown source, that hardly ever is a prize awarded in painting, music or belles-lettres without exciting violent dissent. Usually the next day after the name of the "best novel of 1927," the "gold medal of the Salon" or the "grand prix de l'Académie" is publicly announced, there is an outburst of unflattering remarks about the committee which made the choice. All of the old contentions about the nature and purposes of art flare up; the modernists jeer at the upholders of the classics, and the conservatives retort with ridicule; those who think that art exists for its own sake go to one side, and those who think that it should teach a lesson take the other; and the conflict often ends in passionate appeals to the "verdict of posterity," as though men could not pass just judgments on their own contemporaries.

In the sciences, however, it is generally by much more nearly unanimous consent that eminence is conceded or withheld. It seldom happens that a man is ranked as very great by one large body of his colleagues, as insignificant or stupid by another; and appeals to the verdict of posterity are relatively rare. Is this because the purpose of a science is more definite than the purpose of an art, leaving less room for difference of standards? or because no one cares enough about a science to render an opinion on such a subject or to criticize one already rendered, except the few who are really qualified? or because the commissions and the committees which choose the laureates in science are wiser or more conscientious than those which venture to judge artists? The first two of these, I should say, are certainly contributory causes. It would be a delicate matter to try to prove the third; and yet if one gives any weight to it at all, he must admit that the commission which allots the Nobel Prizes in physics is of a singular discretion; for its awards are greeted as rule with a chorus of applause. Indeed it often seems that the bestowal of the prize has ratified a judgment which was universal though tacit, waiting only for some public sign to give it recognition. This is exemplified by the prizes which have fallen to America; for, among all the living physicists of the United States, the three who have to their credit the most famous of American achievements in physics are certainly those three, who have been crowned by the Swedish Academy of Sciences fulfilling Nobel's will.

Michelson, Millikan and Compton—three names which span the interval from one epoch of physical science to another, though happily the bearers of all three are still among us! Michelson, who carried the undula-

tory conception of light to its utmost limits, and experimented more delicately and more precisely on and with light than any man before him, is an outstanding figure of the *ancien régime* of physics—that period which is fondly remembered as the "classical age," and now seems so remote, even though fewer than thirty years have passed since the beginning of the transition into the new age, even though the old physics is the foundation of the new. Millikan promoted the transition by measuring with unexampled precision the atom of electricity and that other mysterious atom the "quantum of action," which though itself entirely intangible is probably in the last analysis responsible for the subdivision of matter and electricity and light—perhaps of time and space as well, who knows?—into atoms. Compton with his demonstration of corpuscles of light stands forth altogether as a figure of the new era.

To appreciate the work of Michelson in its true setting, one must think himself back as best he can into the classical age—into that time when the Newtonian mechanics, the electromagnetic theory, the wave-conception of light were each in its own field triumphant and had no rivals and seemed adequate in every way—when people quoted with approval that famous dictum that the future of physics lies in the sixth decimal place, meaning that nothing remained to be done except to make better instruments, and with them better measurements, than any which had yet been made. In this field Michelson was paramount. It is now exactly fifty years since he made his debut by a measurement of the velocity of light, which in two years he supplanted by one much better than any which had gone before. Two years later, he made one better yet; and forty-six years after his first publication he returned to his earliest problem, and is re-measuring—for of these experiments one may still speak in the present tense—this all-important constant with such resources of *matériel,* cooperation and experience as were

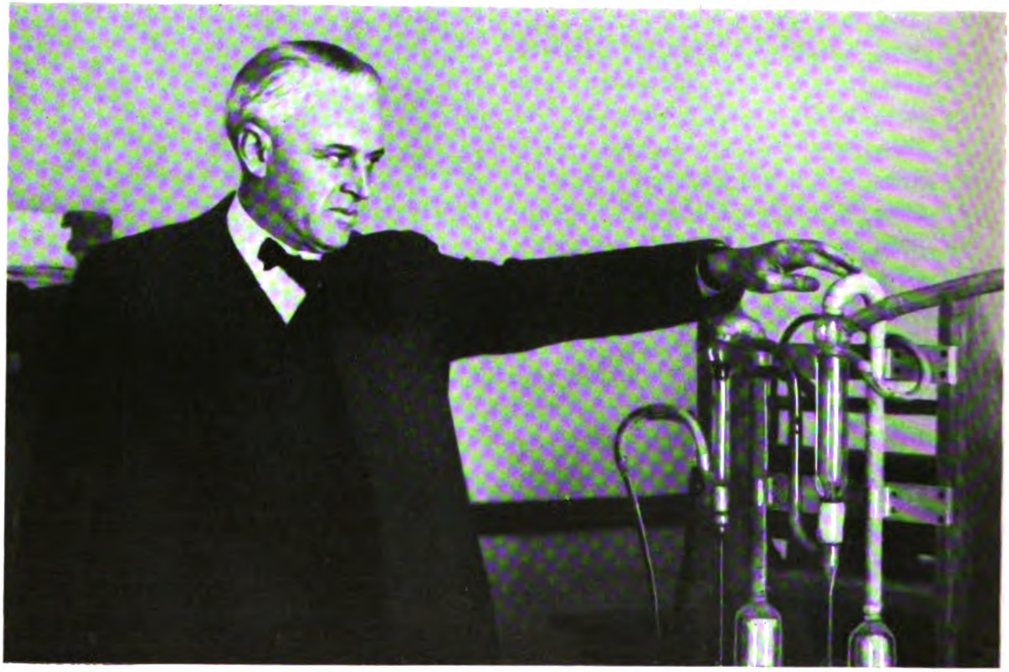


Albert A. Michelson

never before united, having already attained a degree of accuracy far higher than any previous, with a higher one yet in prospect. Tenacity of purpose could not be carried further; and this is not the only instance of the sort in Michelson's career. In 1890 in the *Philosophical Magazine* he described an interference method capable of measuring "the apparent size of minute telescopic objects, such

as planetoids, satellites, and possibly star disks," and of this last-mentioned aspect of the problem, then as now insoluble with any feasible telescope, he wrote: "The possibility of gaining some positive knowledge of the real size of those distant luminaries would more than repay the time, care and patience which it would be necessary to bestow on such a work." Thirty years went past, during which apparently no one else possessed the requisite "time, care, and patience,"—or was it possibly the requisite adroitness which was wanting? and in 1920 Michelson himself made upon Betelgeuse the first measurement in all history of the size of a star. By the test of the saying that *success is a dream of youth realized in mature age,* no man was ever more successful.

Yet notable as are these, it is still another experiment which is the chief basis of Michelson's fame—the renowned experiment, on the negative result of which the theory of relativity is founded. If light is a wave-motion in a medium through which the earth is gliding without displacing or disturbing it, then various experiments can be conceived which should disclose the speed of the earth through this "aether." Various such experiments had in fact been conceived and performed, but there was always some loophole of escape from the conclusion to which all tended—the conclusion, that is to say, that if there is such a medium the earth is permanently at rest in it. Michelson, however, performed, but there was always result of which there was no possibility of escape, shor of making some such strange assumption as that every object moving through the aether shrinks by virtue of its motion, or else remodelling the current notions of time and space. Like most of his



Robert A. Millikan

researches, it involved the interference of light, and required so excellent a technique that in spite of its crucial importance, no one but his collaborators attempted to reproduce it for thirty years. Everything turned on whether or not a pattern of light and dark stripes, the interference-pattern of a pair of beams of light which had traversed different paths through the "aether" if such there were, moved sidewise by a fraction of the width of a single stripe when the entire massive apparatus was revolved through ninety degrees as it floated on a pond of mercury. Not even so feeble an effect as this was seen; and so it happened that one of the outstanding figures of the classic physics unexpectedly became one of the founders of the new.

Millikan's most famous work is another which cannot be appreciated duly, except against the background of its time. Not so very long ago, the obscurest passage to be found in almost any textbook on electricity was the definition of electricity itself. In France there was a joke about a man who had understood everything in Maxwell's classic treatise except the notion of electric charge. There used to be a story of a teacher who asked one of his pupils "What is electricity?" The pupil replied "I am sorry . . . I knew yesterday, but I have forgotten." The teacher turned to the class and said "What a pity! here is the only man in the world who ever knew what electricity is, and he has forgotten!"

Well! nowadays these stories seem to have lost their point; for nearly all of us conceive an electric charge as a cloud of tiny particles, roaming around in space or organizing themselves into systems which are atoms. A philosopher perhaps might say that after all we do not understand an unseen thing the better, when we visualize it as a multitude of particles rather than as a fluid or as an algebraic symbol on a sheet of paper. Still it cannot be gainsaid that the picture helps us enormously in dealing with conduction of electricity and thermionics and photoelectrics, to name only a few of many fields. Now it was Millikan's measurement of the electron-charge *e* which more than any other one thing established this conception.

One must not underrate this contribution by thinking of it as nothing but a measurement. Measurements as such are certainly not to be disparaged, indeed it is said that nothing which has not been measured is a fit subject for physical inquiry; but this was something more. We say that Millikan "measured the constant *e*," as if everyone had known beforehand that there was a constant *e* lying waiting to be measured. That however, in spite of many anticipations and much excellent prior work, was not yet made quite certain. It was the celebrated "oil-drop experiment" which settled that there *is* an electron — that is to say, that any charge of electricity, whatever the body which carries it and however it was gathered upon that body, consists of some integer number of identical and fundamental units.

Droplets of oil or of some other liquid were endowed with charge by many different methods, and the charge on each was ascertained by measuring the rate at which it was drawn upwards through air by an electric field, against the downward drag of gravity upon the liquid mass. Sometimes Millikan would watch a single droplet incessantly for hours,

during which at frequent intervals it gained or lost electric charge of either sign, by capturing ions from the air or by irradiation; after every such event he would observe its rate of rise, and every time the charge turned out to be some integer multiple of the fundamental quantity. So much could be proved, without know-



Arthur H. Compton

ing the mass of the drop; but this had to be known, that the charge might be measured in the stricter sense of the word — evaluated, that is to say, in the standard electrical units. The drops could not be weighed; their weights must be computed from the rates at which they fell through air under the pull of gravity alone, and the formula for computation involves the value of the viscosity of air. Often as experiments had been performed to measure this, the values in the literature were not sufficiently concordant; and beside his major series of experiments, Millikan directed another sequence in which the viscosity of air was redetermined by every method known. Moreover, if a droplet is extremely small, its law of fall through air is not the same as that of the larger drops— it slips, so to speak, between the molecules of the gas. Having established the constancy of e, Millikan inverted his procedure, and taking e for granted he used it to investigate the variations of the law of fall. These I cite to show what unforeseeable by-products a great research may have. Millikan's subsequent work is too extensive by far to be related here, except for the mere mention that for the quantum of action h he later performed the same service as formerly for the electron-charge — measuring it, and by his measurements authenticating it as a constant of nature; for prior to his work it was by no means certain that such a thing existed. Discontinuity was now established in two fields where thirty years earlier it had scarcely been suspected. And this brings us to the work of Arthur Compton.

Compton discovered one outstanding way, in which a beam of light acts candidly and undeniably as though it were a stream of corpuscles. His great experiment was in principle extremely simple. A beam of light of very high frequency, that is to say a beam of X-rays, is projected into a substance containing many nearly free electrons—carbon or lithium for instance, since in the atoms of these elements the electrons are but loosely bound. These then are flung about in all directions, as though the beam of light were a hail of massive particles, knocking out of their way whatever small loose ob-

jects they may strike. Now if these particles of light were bits of ordinary matter, they would be slowed down by any such collision; for a moving body of unchangeable mass cannot give motion and therefore energy to an obstacle which it strikes, except by sacrificing some of its own speed. Light, however, moves with unchangeable speed, and therefore its particles when they give motion to electrons must sacrifice some of their mass. Now it is known, from other phenomena earlier discovered in which light acts as a stream of corpuscles, that the mass of one of these is proportional to its frequency, and reciprocally. Therefore the corpuscles of light which have rebounded from impacts with electrons must be of lower frequency than those which were projected into the "scattering" substance; in the technical language, the "scattered" X-rays are "shifted" downwards in frequency. The exact amount of this shift is definitely fixed by the mass which we are required to assign to the corpuscles of light. Compton established the downward shift, and measured its value, and calculated the value demanded for it by the mass of the corpuscles of light, and found that these agreed. In this way he added a new member, perhaps of all the most immediately striking, to the ensemble of phenomena which are explained by supposing that light consists of corpuscles instead of waves.

Observe, I do not say that he discovered that light consists of corpuscles. For a physicist of the *ancien régime*, there would indeed have been no possible alternative; not however for those whose minds have learned to acquiesce in our strangely inconsistent science of contemporary physics —this science where opposites do not exclude each other, where contradicting statements live amicably side by side, and a dilemma is accepted by grasping both its horns. The undulatory theory of light was not deposed in any domain where it had ever ruled. Interferometers continued to form fringes, and gratings to diffract; and from the spacings of the fringes and the deflections of the diffracted beams, wavelengths continued to be calculated in the same way as they had always been. No one in the optical laboratory or the broadcasting station desisted from speaking of waves; no one ceased to use the wave-theory to determine the resolving-power of a telescope, the arrangement of atoms in crystals by X-ray analysis, or the tuning of a circuit to receive a carrier. Though Michelson on the one hand, Millikan and Compton on the other, appear to stand for opposing tendencies in the development of physics, nothing in Michelson's work is invalidated and nothing is depreciated by the work of his younger colleagues. The province of the wave-theory remains intact, the province of the corpuscular theory is organized beside it. If ever the two are united in some higher synthesis, the wave-picture and the corpuscle-picture will survive as two of its aspects. Meanwhile physicists work onward, hoping that some day the theories will be synthesized, but confident that whether they ever are or not, whatever in either is precious will be faithfully preserved.

Human Errors and the Dial Telephone

By A. O. ADAM
Systems Development Department

DRAWING or making meaningless marks on a memorandum pad is a commonplace diversion while using the telephone, particularly while one is waiting for the person called to answer or to get some information. Spinning the dial, if a dial telephone is being used, is equally instinctive; it is an attractive and apparently harmless occupation for idle fingers. Turning the dial, however, momentarily breaks the circuit and would cause a disconnection had not such a possibility been foreseen by the designers of the system and steps taken to prevent it.



The dial, as it looks to the subscriber

Mounted back of the dial, and controlled by it, are two sets of springs with contacts. One of them, operated at the first movement of the dial away from the normal position, by-passes the transmitter and cuts the receiver out of the circuit; the other, operated during the return of the dial to normal position, opens the line circuit once for each numbered position that the dial moves. The opening of the line is an indication that the conversation has been completed and that the circuits associated with the call can disconnect. Since rotating the dial causes a series of line-opens the result of idly playing with it during a conversation would normally be a disconnection.

The disconnect signal in the manual system is caused by holding down the switchhook which lights a lamp in front of the operator. When the subscriber moves the switchhook up and down rapidly, however, a series of short flashes results which the operator knows is not a signal to disconnect, and she listens in on the line to discover what is wanted. To simulate the manual operator in this respect it is necessary to arrange dial-circuits so that momentary line-opens can be tolerated.

In the panel system* a definite time interval has been introduced through the action of an interrupter which guards against disconnection on short line-opens but yet recognizes long line-opens as a disconnect signal. The time interval is such that a line-open must be in excess of a quarter second

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** This article deals only with the panel system; analogous precautions embodied in the step-by-step system will be described in a future issue of the* RECORD.

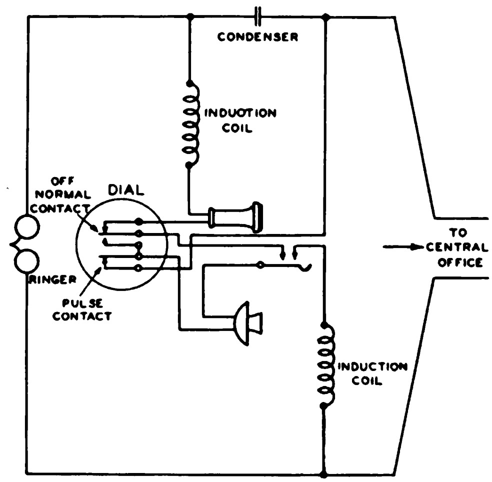
in order to cause disconnection. It would be desirable to permit a longer period, but, due to variations in the apparatus, it is not practicable to do so and at the same time insure that a subscriber will not meet with delay in originating another call.

The time interval introduced does not, of course, prevent all possible disconnects due to short line-opens but reduces the number of them and eliminates particularly those which are most likely to be accidental.

When dialing a number with a repeated final digit such as Chelsea 1000, it is quite possible for the subscriber to become uncertain regarding the number of zeros so that in many cases an extra one is dialed. Here again if it were not for the time-delay feature preventing disconnect, the line-opens caused by dialing an extra digit would result in a disconnect. As it is, however, any final digit may be repeated without causing trouble.

This is only one of the many possible human errors in dialing that have been foreseen and forestalled by building into both panel and step-by-step systems special mechanisms to lighten the subscriber's responsibility. To better understand how this is accomplished in the panel system it will be necessary to take a bird's-eye view of the operation of completing a call.

When a subscriber in a manual office removes the receiver from the switchhook a lamp associated with the line is lighted at the switchboard. The operator answers by plugging a cord into the jack indicated by the lamp and switching the talking key so as to obtain the desired number from the calling subscriber. In the panel system the first operation, similarly, is to find the calling line. This is accomplished by a "line finder" which, associated with a district selector, corresponds to the operator's cord. The district selector in turn connects to a sender, and this entire group of operations is usually completed before the subscriber can lift the receiver to his ear. The sender corresponds to the operator and re-



Wiring diagram for subscriber's set showing how dialing opens the circuit

cords all the information required for completing the call. A relay in the sender circuit is bridged directly across the subscriber's circuit and pulses caused by the opening and closing of the dial contacts are transmitted by this relay to a registering circuit which records each digit dialed.

A subscriber, due to some mishap such as dropping the desk stand immediately after removing the receiver from the switchhook, may flash the receiver hook before dialing the first digit. This causes a momentary opening in the circuit and is equivalent to dialing 1. The digit 1 is now falsely recorded in the sender circuit so that a wrong number would result. The subscriber probably does not realize what has occurred and continues dialing. The sender circuit, however,

has been arranged to cancel this first false pulse. This is made possible by designing the sender registering circuit so that if a 1 is dialed as the first digit of an office code the following digit instead will be recognized as the first.

Instead of recording all the dial pulses caused by the second operation of the dial, the first pulse is cancelled and the remaining pulses are added to the 1 which is already recorded. Thus if a 1 were dialed followed by a 5, only four of the five pulses from the dial would be used, and these added to the 1 already recorded would result in a correct registration of 5. This makes it possible for the subscriber to obtain the correct number even though a false pulse has been sent prior to dialing the first digit of the office code. It eliminates, however, the possibility of having an office with 1 as the first digit.

Another error likely to occur during dialing is caused by confusing the letter O with the number 0. The ten positions of the dial are numbered consecutively from one to nought and eight of them, two to nine inclusive, have each three letters in addition, Q and Z alone being omitted. In large areas each subscriber's number requires seven or eight dialing operations, three to locate the central office for which the letters are used, and the remaining four or five to locate the subscriber within that office. If a call were to be made to an office such as Monument which contains an O in the first three letters the subscriber might easily dial the number nought in place of the letter O. The correct office code would be the equivalent of dialing 666, each operation of the dial making six successive breaks in the circuit, but if the number 0 were dialed in place of the letter O the resultant office code would be 606, so that the second dialing operation would make ten breaks in the circuit.

Although the subscriber alone is responsible for this, it is advisable to make such an error harmless. The difficulty has been overcome by designing the sender circuit to recognize the letter O—six breaks—or the number 0—ten breaks—when dialed as part of the office code, as being identical. This makes it possible for the subscriber calling a person in the Monument office to dial 600, 606, 660, or 666 as the office code and still be directed to the proper office. This same immunity can not be given when the number 0 is dialed in error for the first letter, as the number zero is reserved to call the operator: the subscriber's service is safeguarded, however, by the operator being brought in on the connection.

The foregoing gives some idea of the various small details that must be considered in attempting to render better telephone service. The effort has been made not only to develop a system that will work satisfactorily if it is handled correctly but one in which no likely mistake in the use of the dial can cause inconvenience to the subscriber.

The foregoing gives only a few of the human errors possible in dialing and explains how they are rendered harmless in the panel system. Similar methods are used in the step-by-step system to accomplish the same purpose. The effort has been made not only to develop a system that will work satisfactorily if it is handled correctly but one in which no likely mistake in the use of the dial can inconvenience the subscriber.

Speech Interpretation in Auditoriums

By E. C. WENTE
Research Department

THAT different auditoriums of approximately the same size vary greatly in their acoustic properties is apparent even to the casual observer. In some halls it is difficult to follow a speaker who might be heard easily in a room with better acoustics. An auditorium which is acoustically bad for speaking purposes usually has one or the other of two defects; either the speaker's voice is too faint at remote points, or, on account of excessive reflections from the walls, the spoken syllables do not reach the ears of the listener as articulate sounds but as a chaos of tones, from which he can extract the meaning only by a tiring effort.

In the open air, words reach the listener directly from the speaker; in a closed room, however, they are reinforced by reflection from the enclosing walls. This gives rise to the phenomenon that in a room a spoken syllable is heard for some time after it is uttered, and the greater the reflecting power of its walls, the longer is this time of reverberation. If the room has hard walls the loudness of one syllable at some distance from the speaker may still be great enough to interfere with the interpretation of the succeeding syllable. There are thus two extreme conditions: if the walls are highly absorbing, the loudness of the speech at remote parts of the room may be insufficient; if the walls are hard, the loudness will be almost the same at all parts of the room but the excessive reverberation will make it difficult to distinguish the individual syllables of the speech. Obviously in the design of an auditorium these two extreme conditions must be avoided.

The late Professor Sabine of Harvard conducted a series of noteworthy experiments in which he set up as a measure of the acoustics of an auditorium the time required for the average sound-energy density to fall to one millionth of (60 TU below) its initial value. This time is technically designated as the reverberation time. Sabine found that for a given size of room it has an optimum value. Most of his data, however, refers to sounds of a frequency of 512 cycles, which lies near the middle of the musical scale. The absorption of sound by materials, however, varies greatly with frequency. Hence even rooms having the optimum reverberation time at 512 cycles may yet vary widely in their acoustic characteristics. Sabine recognized this fact, but it was not sufficiently stressed, especially with reference to the interpretation of speech.

Speech sounds may be regarded as composites of pure tones of different frequencies and intensities. The distribution of energy among the component tones of representative English speech sounds throughout the frequency range from fifty to five

thousand cycles per second has been determined by Crandall and MacKenzie.* Their results are shown in Figure 1. Curve A gives the relative amount of energy in speech corresponding to the frequency shown as abscissa. In the region around two hundred cycles there is approximately forty times as much energy as around fifteen hundred cycles. Curve B gives the energies plotted in a little different way. Here the ordinate gives the fractional part of the energy that lies below the corresponding frequency plotted as abscissa. This curve shows that sixty per cent of the energy in speech lies below five hundred and thirty-five per cent below two hundred cycles.

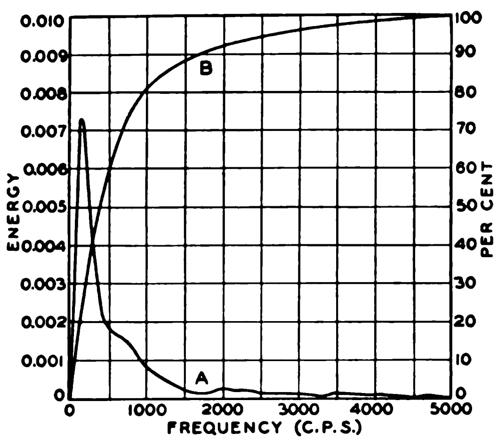


Fig. 1 — Energy distribution in speech. A, Relative energy at each frequency. B, Per cent of energy below given frequency

In view of the preceding data it might seem that the low frequency components in speech are relatively important. However, it has been shown that, although the components in speech lying below five hundred cycles are of value in preserving the naturalness of a speaker's voice, they contribute relatively little to the interpretation of speech sounds. The curve shown in Figure 2 is from a paper by Fletcher.* This curve gives the percentage of syllables found in the English language which are correctly understood when all the energy below the frequency given as abscissa is suppressed by the transmitting system. For example, if all the energy below five hundred cycles is suppressed, the articulation is still within two percent of the maximum, although sixty percent of the energy in speech lies below this value. This fact points to the importance of considering the absorption characteristics of materials that are used in rooms for damping purposes.

In Figure 3 is shown the absorption curve for a layer of hair felt such as is frequently used for deadening rooms. This material is merely given as an example; most other types of porous materials used for this purpose have very similar absorption characteristics. This material is seen to have large absorp-

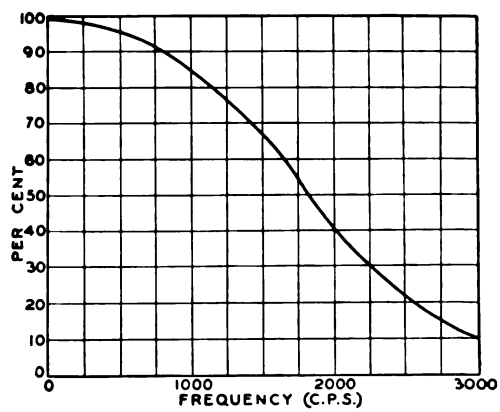


Fig. 2—Syllable articulation when energy below given frequency is suppressed

* Physical Review, *XIX p.* 221, *March*, 1922.

* Journal of the Franklin Inst., *June*, 1922.

tion in the upper but small absorption in the lower frequency region. The average intensity throughout a room is, to a first approximation, inversely proportional to the absorptivity of all the surfaces. Hence, in a room with a relatively large amount of porous materials, the intensities of the tones of the higher frequencies, which we have seen to be important for articulation, are very greatly reduced in comparison with those of the lower frequencies, which are unimportant for articulation. When, then, enough porous material is introduced to reduce the reverberation of those tones

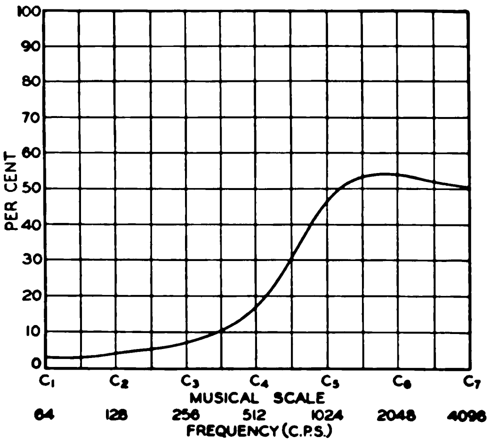


Fig. 3 — *Absorption of hair felt*

in which speech is rich to the point where it is no longer objectionable, the intensities of the important high frequency tones may be below the threshold of audibility at remote parts of the room. At these points it will be difficult to interpret the speaker's words.

Aside from the distracting effect of the reverberation of low frequency tones, their presence in excessive amounts reduces the ability of the auditor to hear those of high frequency. It has for a long time been known qualitatively that the threshold of audibility for a given tone is raised by the presence of another tone, especially if this tone be one of

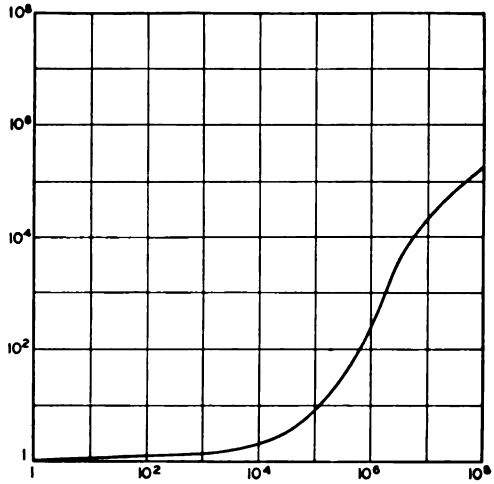


Fig. 4 — *Masking of* 1500-*cycle tone by* 300-*cycle tone*

lower frequency. A quantitative study of this masking of one tone by another has been made by Wegel and Lane,* from whose paper the curve of Figure 4 is taken. An ordinate of this curve gives the relative power of a 1500-cycle tone that is just audible in the presence of a masking tone of three hundred cycles having the power indicated by the abscissa. Unity power for either tone is taken as its power at the threshold of audibility when no other tone is sounded simultaneously. For example, when a tone of three hundred cycles is sounded at an intensity of $10^{6.8}$ times its value at the threshold of audibility, a fifteen hundred cycle tone to be heard must be 10^4 times as intense as when the three hundred cycle tone is absent. These values of intensities for the respective frequencies are quite possible for speech in a room, which has its

* PHYSICAL REVIEW, *XXIII, February,* 1924.

acoustic characteristics controlled by the absorption of ordinary porous materials. The phenomenon of masking further emphasizes the importance of keeping down the average intensity

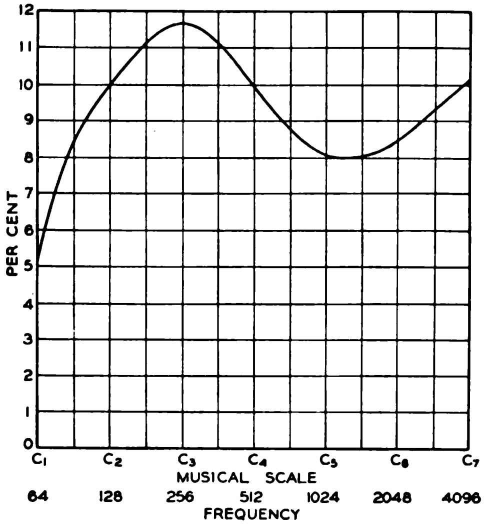


Fig. 5—*Sound absorption of wood paneling*

of the lower tones, which for articulation are quite unimportant and yet are delivered in large amounts by the speaker.

The conclusions here reached, while resting primarily on indirect data, seem to be borne out by experience. Auditoriums having the most desirable acoustic properties are found to be those which are sufficiently dead but are free from hangings and other porous materials. Many of the best auditoriums have a large amount of wood paneling. Figure 5 gives the absorption curve for such paneling as determined by W. C. Sabine. This is seen to be somewhat selective in favor of the lower frequency tones. For a room that is too reverberant we could thus hardly do better than to increase the absorption by covering certain of the walls by some kind of wooden panels. Unfortunately, as the absorption coefficient for such panels is low, a very large amount of wall space would usually have to be covered in order to bring the reverberation down to a proper value. This the fire laws will not permit in many cases. It thus appears that there is a need for a material which is fire-proof, fits into the decorative scheme of interiors, and has absorption characteristics that are high and selective for low frequency tones. Having available materials of this type in addition to the various porous absorbers now on the market we could place the problem of acoustic treatment of rooms on a better engineering basis.

Critical Relays of the Telephone Systems

By W. KUHN
Systems Development Department

TO INSURE that a telephone call reaches its proper destination, many close races against time must be run and won by the telephone apparatus. To those initiated into the secrets of telephony these races are fully as interesting and fascinating as those being run in the sporting world, for where these latter take into account days, hours, minutes, and possibly seconds, a race in a telephone circuit is only a matter of a few thousandths of a second.

Entrants in the races occurring in telephone circuits are generally relays, which are among the most important elements of the telephone system. The number required for a single call varies from approximately twenty, used to complete a call between manual subscribers, to about three hundred required to complete a connection between subscribers in widely separated areas. All of these relays must be reliable and accurate, particularly those upon whose correct operation the satisfactory progress of the call directly depends.

Fundamentally a relay is an electrically operated switch. It consists of an electromagnet (core and winding), and armature, and contacts. These parts are so arranged that when the core becomes magnetized by an electric current through its windings, the armature is attracted by the core and moves sufficiently to open or close the associated contacts. The speeds at which the armature responds to the make and break of the current through the winding are important. The elapsed time from the instant the current starts to flow through the winding to the moment the contact closes is known as the "operate time," and similarly that from the opening of the winding circuit to the opening of the contact, as the "release time." These are shown graphically in the oscillogram study of a relay operation on Figure 1.

Just as the competitors in a recent

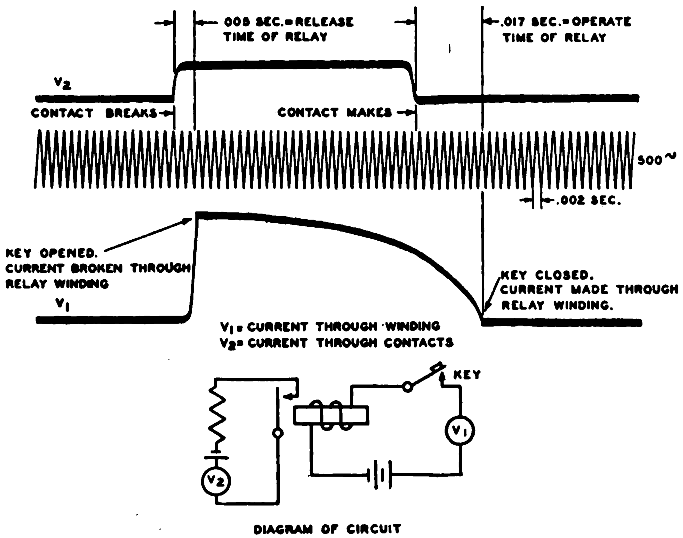


Fig. 1 — *Oscillogram showing "operate" and "release" times of a relay in a typical circuit*

cross-continental race were required to run under a variety of weather conditions, some of which were adverse, so the apparatus in the telephone system must function properly over a great variation in circuit con-

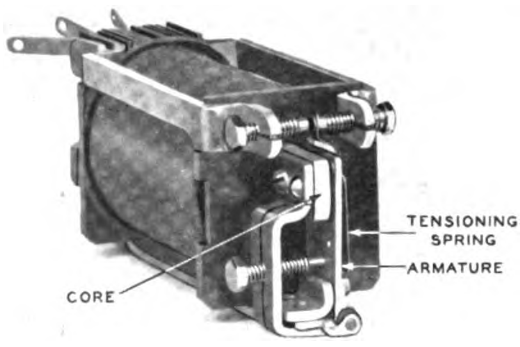


Fig. 2 — An L type relay which finds many uses in telephone circuits where fast "operate" and "release" are required

ditions. A minimum variation in the time characteristic (operate and release times) is desirable, but this is sometimes difficult to obtain on account of circuit variations under which the relays are required to function.

Many types of relays used in circuits where special speed requirements are to be met, must operate over a wide range of current, and yet release when there is still some current flowing through the winding. These may well be called critical relays. Operating range in many such cases depends upon the distance between central offices or between a subscriber and a central office, which may vary from a few yards to many miles. The current against which the relay is required to release is that flowing through the insulation of the conductors, which is something impaired by damp weather. This small leakage current flowing through the relay causes it to release more slowly.

Another factor which considerably affects the constancy of relay operating-times is variation in central office voltage. In manual central offices this may vary from twenty to twenty-eight volts for rated twenty-four volt circuits or from forty to fifty-six volts for rated forty-eight volt circuits. The corresponding voltage ranges in dial-system circuits are twenty-one to twenty-five, and forty-five to fiftv volts, respectively. It is evident that a relay operating over long cable loops on minimum voltage will be slower in operating than one operating on maximum voltage on shorter

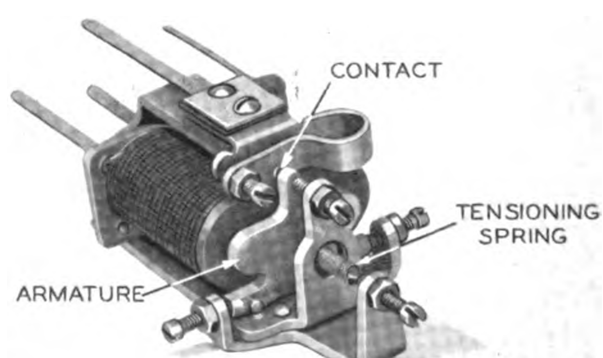


Fig. 3 — Having, like the L type, very fast "operate" and "release" times, the stepping or 207 relay is used for but one purpose in the Bell System

lengths of cable. Similarly, a relay compelled to release against leakage currents will act more slowly on maximum than on minimum voltage.

The particular critical operating and releasing characteristics required depend upon the circuit conditions under which the relay is used. In the sender circuit of panel-type equipment, for example, the "pulse" relay must accurately follow the make and break of the contact of a subscriber's dial. If the operate and release times of the relay are such that it will not faithfully repeat these pulses, the selector which registers them will not have sufficient time to function, and the call will be routed incorrectly. Furthermore, unless the armature of the pulse relay has sufficient spring tension the relay may operate falsely due to the discharges of cable capacity and the condensers in the subscriber's set, or to the cable-inductance. This would result in a false registration of pulses and a wrong number. Although a "stiff" adjustment of this relay prevents false operation, it necessarily limits the length of cable over which the relay will operate. The relay which performs this function must be fast both in operating and releasing. For this purpose an accurately adjustable model is used equipped with a light armature having a low moment of inertia. The "L" type relay shown in Figure 2 meets these requirements, and is used as the pulse relay in all the newer sender circuits. It operates over wide ranges with very little variation in its operate and release times.

Another relay which performs an extremely important function in the sender circuit is the stepping relay. Located in the originating office, it must reproduce the pulsations of current originated by the selectors in the terminating office with sufficient accuracy to insure the operation of fast-operate counting relays. The stepping relay also must have extremely fast operate and release characteristics and since it derives its driving current over trunk loops, is subject to cable discharges similar to those experienced by the pulse relay. To perform its task a very delicate and highly sensitive relay is required. Here the 207 relay shown as Figure 3 is used and serves no other purpose in the telephone plant.

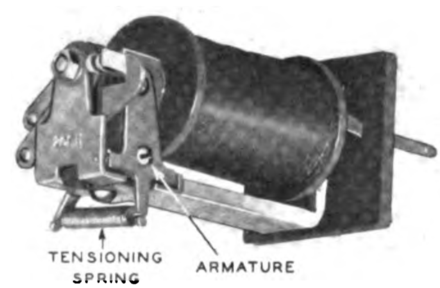


Fig. 4 — The 208 type or counting relay; one of the high-speed relays of the Bell System

Counting relays of the sender cirsuit serve as another example of very accurate high-speed relays. These are among the fastest relays in use in the telephone plant. They are required to function from the contact of the stepping relay. The operate time of these relays is of the order of five thousandths of a second and is very constant. This high degree of constancy is possible because the relays operate in a local circuit and are not required to function over such great circuit variations as the pulsing relays. The high speed of these relays can be more readily appreciated by comparing it with that of an automobile

going sixty-five miles per hour, which travels only six inches in the operate time of one of them.

The 208 type counting relay is shown in Figure 4. It is equipped with a light armature on a pivot suspension, and operates through a small air gap. The contacts are mounted on comparatively rigid springs which, once adjusted, maintain the adjustment without change for a considerable time.

Other circuit conditions require slow-acting relays which yet must function within the time limits set by the circuit requirements. Slow-acting relays may be slow operating, slow releasing, or both, and are used for various purposes. One of the more important is the "register advance,"

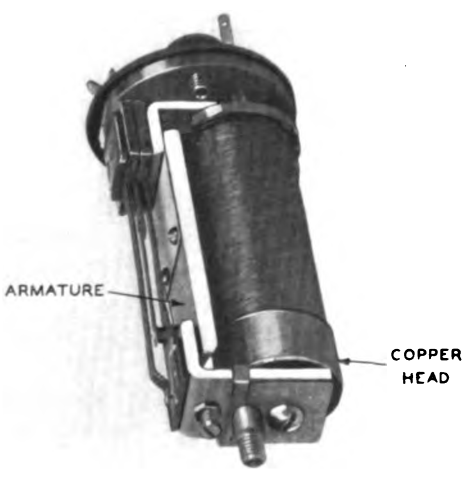


Fig. 5 — Slow-acting relays have heavier armatures and copper heads, as may be seen in this 149-BR relay

or "steering" relays—a relay in the sender circuit closely associated with the registration of the dial pulses. Its function is to insure the registration of the dial pulses of successively dialed digits on the correct registers.

Operated by the first closure of the pulse relay contacts the "steering" relay is designed to remain operated during the individual make-and-break periods of the dial pulses, and to release during the break periods between the dialing of successive digits. If the relay releases either too quickly or too slowly, the dial pulses are registered on the wrong register and an incorrect number results. Because of the narrowness of the time limits which the relay is required to meet, considerable study is required to obtain a relay which will perform satisfactorily. Many sender circuits use for this purpose the round-core slow-releasing 149-BR relay illustrated in Figure 5, This relay, equipped with a heavy armature and a copper head, is typical of the slow action relays used.

Another illustration of the importance of the time element in operation is found in the supervisory relays. These, as well as the pulse relays, must operate over subscribers' and trunk loops which vary from practically zero resistance to the maximum resistance through which the relays will operate, and must release against small leakage currents tending to hold them operated.

Supervisory relays in cord circuits are usually required to flash a lamp or other signaling device. A subscriber in a manual area wishing to recall an operator moves his switchhook up and down, thereby operating and releasing a supervisory relay, and alternately lighting and extinguishing a supervisory lamp in front of the operator. Such relays must respond quickly so that the period between operate and release is greater than the time required to light the lamp filament or to operate the signal. The visible signal received by the operator

is therefore dependent on the ability of the supervisory relay to quickly follow the make and break of the subscriber's switchhook.

Some supervisory relays are required to repeat a "reorder signal" of 120 interruptions per minute when relayed from the terminating office through the contacts of one or more other supervisory relays. This flashing signal tells the operator in the originating office to repeat the called number to the operator in the terminating office. Relays required to repeat the flash to these supervisory relays must also function over trunk loops, and on extreme circuit conditions each one distorts the signal by changing the original length of the make and break periods of the reorder pulse. Under these conditions it is difficult to insure that the "A" operator will obtain a visible flashing signal.

Because most supervisory relays are connected in series with the line outside of the repeating coil it is necessary, in order to obtain a low impedance path for voice currents, to use a non-inductive shunt in parallel with the inductive winding of the relay. This tends to give the relay slow operate and release characteristics which are undesirable for flashing. To overcome this undesirable tendency supervisory relays are designed to operate and release at a rate of 180 per minute under testing conditions. The "B" type relay shown in Figure 6 is the type most used for supervisory purposes.

These are but a few of the more prominent examples of the circuit conditions which require critical relays. In many cases where time is not an important factor the current-flow conditions are critical. A relay may be required to differentiate between operate and non-operate current differing in magnitude by only a small amount. In each case relay adjustment plays a vital part in obtaining

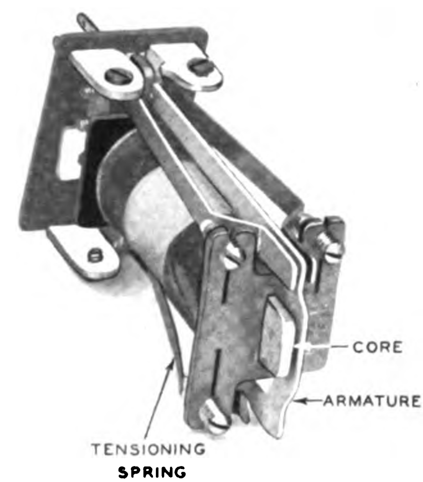


Fig. 6 — A "B" type relay used for supervisory purposes

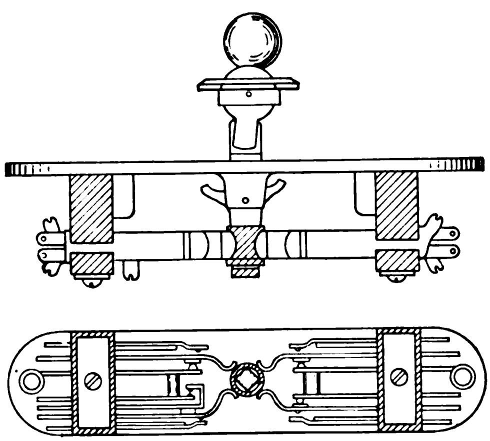
satisfactory operation. The design of the relay structure and particularly of the movable parts has a considerable effect upon its characteristics and its suitability for the circuit condition in question.

To make sure that relays will function properly in service, thorough tests must be made in the laboratory before they are approved. Tests are also continually in progress to increase the operating ranges, and to determine the adjustments for most satisfactory operation.

Lever-Type Keys

By G. A. RITCHIE
Apparatus Development Department

OF THE great variety of keys used in manual telephone switchboards, the lever keys are the most characteristic and probably the most useful. The earliest of these to come into general use in the Bell System was the 52 type, used for ringing and listening, on which application for a patent was filed in 1888. In the key itself two spring combinations, with a swinging cam between them, were mounted in a frame of cast brass which was fastened to the under side of the wooden keyshelf. A lever was mounted directly above, in a separate frame, and



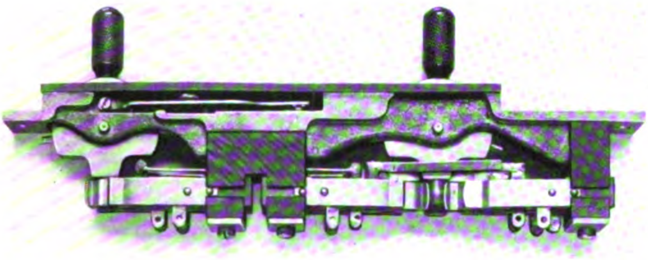
A 51-type key, the first key lever key containing two pileups

engaged a slot in the cam of the key so that movement of the lever was transmitted to the cam. These keys were generally used until, with the inception of two-party selective ringing systems, it became necessary to provide in each cord circuit two spring combinations for ringing in addition to the combination for listening.

To meet the new demand with the addition of another spring combination and another lever the 102-type key was brought out. Opportunty was taken in the new design to facilitate mounting by several important changes in construction. The levers were made integral parts of the key rather than separate assemblies; the key frame was changed in shape and finish to form part of the upper surface of the keyshelf; and mounting lugs were added at the front and back of the frame. At the same time the keyshelf was redesigned with a rectangular opening to hold the customary number of keys. At the front and back of the opening were mounting bars, to which the keys were bolted. The upper surface of the lug was below the surface of the keyshelf, and after installation lugs at front and back were covered with wooden retaining strips parallel with the edge shelf. This construction afforded greater flexibility in mounting, since it eliminated the need for cutting new holes when the key spacing or centering was changed at any installation.

The horizontal arrangement of the springs made them easily accessible for inspection and maintenance, since the edges were exposed when the hinged shelf was raised. This fea-

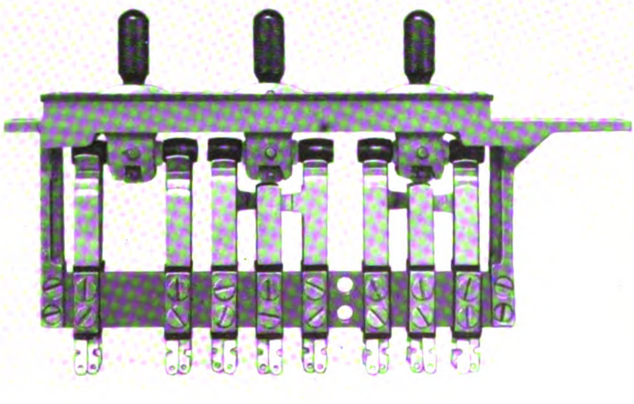
ture, together with the substantial construction, made the 102-type keys so satisfactory that many thousands of them are still in service. However, the side-by-side position of the springs made the minimum width possible for a particular key dependent principally on the number of springs in its largest pileup. Only a moderate width was necessitated by the number of contacts used at the time, but later circuits, requiring a larger number of springs, would have increased the width to such an extent as to cut down the number of cord circuits with which a keyshelf could be equipped to a figure below that for the most efficient handling of calls. Furthermore the introduction of prepayment coin-box service made necessary keys with more spring combinations to provide for collection and return of coins in addition to ringing and listening.



A key of the 102-type. Although the design has since been changed in almost all respects, this type marks a major step toward the keys of today

Two new types of keys, similar in design, were thereupon developed, the 462 and 463. The 463 type key was equipped with three levers, while in the 462 the rear lever was replaced by two push buttons for collection and return of coins, or by a single push button for operation of a message register. The springs were mounted vertically, and as a result six groups of springs were provided in keys the same length as those of the 102 type, where there had been room for only three. The pileups still extended sidewise, however, so that increase in the number of springs meant greater width, but some additional spring capacity was obtained when needed by providing an auxiliary set of springs between the two main spring combinations of each lever, operated by extensions protruding from the springs of the main pile-ups.

To meet the demand for larger spring combinations brought by the standardization of improved operating practices the present standard

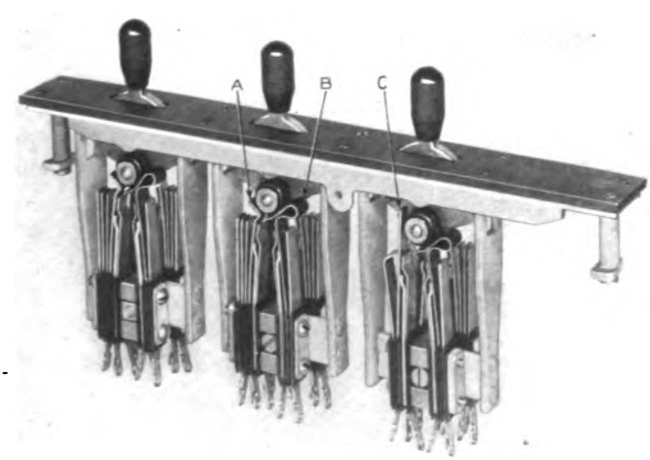


A 463-type key, with auxiliary springs beneath two of the levers

keys of the A1 and A2 types were developed. A radical change in construction brought advance from the standpoints of manufacture, installation and maintenance, as well as in the number of contact springs that could be accommodated. The heavy frame of cast brass formerly used was replaced by a channel pressed from light sheet steel, to which are bolted subordinate frames for holding the spring pileups and the levers or plungers. Thus unit construction was introduced. Whenever a new key was wanted its production involved the comparatively simple process of combining standard units, rather than the previous course of designing and manufacturing an entirely new entity.

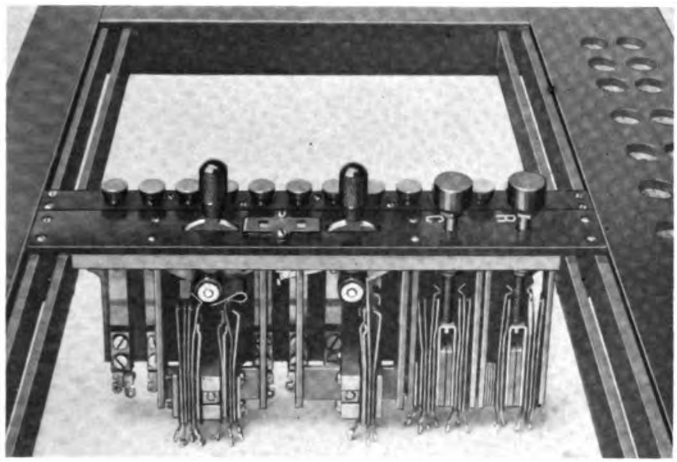
The springs are vertical as before, but they have been turned through 90 degrees so that their surfaces are parallel to the edge of the keyshelf. With the springs extending from front to back rather than from side to side, width is independent of the number of contacts in a pileup. At each corner of the sub-frame associated with a lever is a pileup in which there may be a maximum of seven contact springs. When the lever is moved in either direction two rollers supported by pins on opposite sides of the cam operate a pair of the pileups, and thereby as many as fourteen contact springs, a number sufficient for all standard circuit conditions encountered at the present time.

In one pileup of each pair there is a spring, longer than the others, which transmits the motion of the roller on the lever cam to the other springs. This plunger spring may be straight, to restore the lever to normal as soon as it is released, or made with a V-shaped crimp for holding the lever operated until restored manually. In the other pileup of the pair motion of the cam roller is taken by a long curved spring, commonly called a crook spring from its fancied resemblance to a shepherd's crook. The reason for its peculiar shape is its main function, that of preventing even momentary false operation of any of the contacts. After release of a lever from either operated position one of the rollers, passing the neutral position, strikes the crook spring at the opposite side; flexing of the spring absorbs the energy of lever and cam before the rollers have gone far enough to operate any of the contacts.



A-1 type key, showing the mounting posts and the auxiliary frame supporting each lever unit. A, plunger spring with crimp; B, crook spring; C, straight plunger spring

The method of mounting in the keyshelves has also been simplified. A small post is provided at each end of the key base, with a threaded hole at the end, into which is inserted a screw bearing a narrow, flat-sided washer. These posts pass through a space between pairs of parallel mounting bars at the front and rear of the opening in the keyshelf, and are held in place when the washers are turned through 90 degrees and the screws tightened. The redesign of key frame and shelf has made it possible to keep the top surfaces of the keys level from end to end. The wooden retaining strips which ran across the front and back of the key-shelves, covering the lower ends and the mounting screws of previous keys, have therefore been omitted.



An A-2 type key mounted in a keyshelf, with the posts between the mounting strips at front and back of the shelf

By these changes in construction, the work of mounting keys has been greatly facilitated. It is no longer necessary to drill and tap the mounting bars of the keyshelves, but merely to place a key in position, give the clamping washer at each end a quarter turn and tighten the screw. Removal of a key to give access to the springs has likewise been simplified of course; loosening the two screws and turning the clamping washers takes the place of removing two retaining strips and a number of screws, formerly necessary to get a key out.

Construction of the pileups has made possible a wide variety of spring combinations from a small range of individual parts. That this feature is of major importance is shown by the facts that more than 500 types of spring combinations are now in use, and that this number is being steadily increased to meet the needs of new circuit developments. When plunger-type units are mounted on any of the keys, for coin-box or message-register operation, each is assembled on a frame punched from sheet steel, just as the lever units are; two such plunger units take up about the same space as a single lever unit. Practically all lever-type keys of recent design are of three standard lengths, accommodating respectively one, two and three lever units; in the last of these two plunger units may be substituted for the rear lever unit. Call circuit keys and mechanically locking keys are made with a similar type of unit construction, and use the channel frames of standard lengths.



WILTON L. RICHARDS

Fifty Years of Bell System Service

ON September first, 1878, a telephone career began which has proved one of the longest in the telephone industry. Wilton L. Richards, entering that day the shop of Charles Williams in Boston, has seen telephony unfold from a scientific marvel into a close-knit system spanning continents and oceans. At first as the assistant of Francis Blake in installing his transmitters, and of Emil Berliner in his researches, Mr. Richards began a fruitful career in telephone transmission. Every operator, listening unconscious of the receiver which sits lightly on her head, is equally unconscious that Mr. Richards developed the first practical head-receiver. The bipolar receiver, which hangs from every desk-stand, traces its ancestry through Mr. Richards' development of the "long distance" instrument of 1890. Today's broadcasting was presaged by his work on transmitters to pick up theatre programs.

Telephone lines, too, came under Mr. Richards' attention; he was associated with G. A. Campbell in the early transmission measurements of circuits and their equipment which led up to the use of loading by the Bell System. In the first days of the vacuum tube, Mr. Richards made numerous tests of their application to our needs. His interest in repeaters led to the conception and an original development of the balanced-circuit method by which a two-way channel is split into two one-way channels; this operation is performed in every 22-type repeater and every linkage of wire circuits to radio for two-way communication. A number of other patents also stand to his credit which include protective devices, loading-coil arrangements, telephone receivers and transmitters.

Mr. Richards had much to do with the Bell System exhibit at the Chicago Worlds Fair in 1893, and in 1915, he was in charge of the transmission features of the exhibit at the Panama-Pacific Exhibition at San Francisco. At about this time he was placed in charge of the Historical Museum at West Street. It is to his historical knowledge, painstaking care, and enthusiasm that the Museum in its present form is largely due.

The beginning of his fifty-first year finds Mr. Richards as Consulting Historian of the Laboratories an active member of the Bell System which he has served so long, proud of the wonderful growth and communication accomplishments of the System and happy in the affection of his many friends.



Above, left, Henry Olsen; right, Otto Muller; center, Mary Lindner; below, left, Frank Meehan; right, John Lawless

Recent Retirements from Active Service

By A. F. WEBER
Secretary, Employees' Benefit Fund Committee

SINCE August of last year the Laboratories has lost the services of five of its members through their retirement under the provisions of the Plan for Employees Pensions, Disability Benefits and Death Benefits. Leaving us as they do after years of service, they should carry with them the pleasurable knowledge that their individual efforts have contributed to the development of the Laboratories today, and that their friends, whom they leave behind to continue its work, wish them many years of health and happiness.

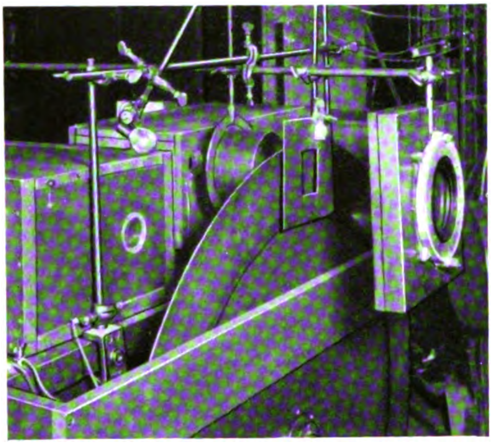
Miss Mary Lindner, who has most recently been a technical assistant in the lamp and battery group of the Apparatus Development Department, since the granting of her application for retirement last November has been living with her sister and niece in Bayonne, New Jersey.

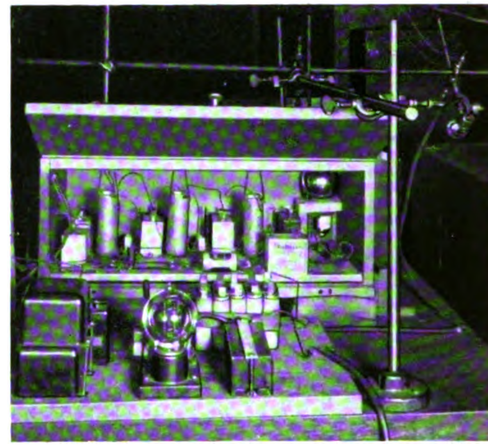
Frank Meehan, whose genial face has been missed for some time from the 1-C entrance on Bethune Street, was also retired at his own request after twenty-three years of service with the Western Electric Company and Bell Telephone Laboratories as a porter and watchman.

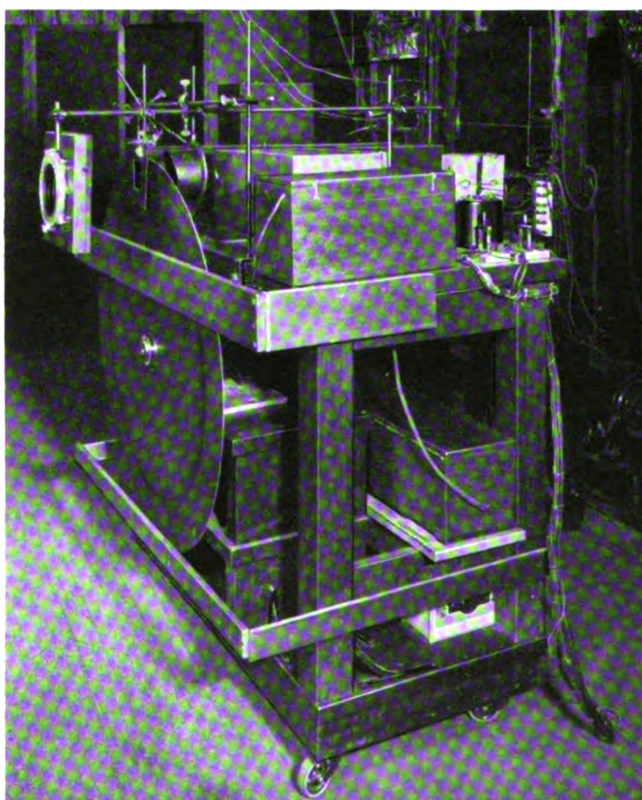
Henry Olsen, who was at the time of his retirement a supervising draftsman in the Systems Development Department, is now living on his farm near Saratoga Springs, New York.

John Lawless, who has been continuously employed in the Plant Department of the 463 West Street building since joining the Western Electric Company in 1901, requested his retirement because of failing health but continues his residence in Greenwich Village where he has been living for the past seventeen years.

Otto Muller, the "grand old man" of the Engineering Shop, shortly after celebrating his eightieth birthday, requested retirement so he might enjoy his leisure while still in good health. Mr. Muller has not been absent for sickness or other reasons for almost five years. Entering the Western Electric Company in 1892 as a skilled mechanic in its Manufacturing Department, he has been continuously employed on the more difficult and accurate work such as that requiring diamond cutting-tools. His ability especially fitted him to be retained in our Engineering Shop when manufacturing work was transferred to Hawthorne in 1913.







Television by Direct Scanning

Set up outdoors last July, the transmitter (center) viewed a scene illuminated only by daylight. Brought by the large lens to a focus, the image was scanned by holes in the rotating disc. In the box (upper right) appear the cell and the first three amplifier tubes in their lead jackets. Black-and-white segments on the back of the disc, illuminated by the lamp (upper left), are viewed by a second cell to furnish alternating current for synchronizing

News Notes

A VISITOR to the Laboratories on September 6 was Professor Jonathan Zenneck of Munich, upon whom the Institute of Radio Engineers recently conferred the Medal of Honor. Dr. Zenneck, escorted by W. Wilson, inspected the laboratories for radio research and for electronic physics. Accompanied by R. A. Heising and F. M. Ryan he then visited the radio laboratory at Whippany.

SEVERAL LABORATORIES ENGINEERS were present at the fall meeting of the Society of Motion Picture Engineers, held at Lake Placid, New York, during the week commencing September 24. Several papers on sound recording were read, including "The Quality of Speech and Music" by J. C. Steinberg, "Sound Reproduction in Theatres" by E. O. Scriven of the Laboratories and H. B. Santee, of Electrical Research Products, Inc., "Recent Advances in Wax Recording" by H. A. Frederick, "Light Valve Recording" by Donald MacKenzie, "General Principles in Sound Recording" by E. C. Wente, and "Methods of Synchronizing" by H. M. Stoller.

Patent

C. A. CONRAD, H. A. FLAMMER AND T. P. NEVILLE visited Washington in connection with the prosecution of applications for patent. J. A. Hall visited Rochester and I. MacDonald visited Philadelphia for the same purpose.

General Staff

S. P. GRACE addressed the Convention of the New Hampshire Telephone Association at Laconia, New Hampshire, on September 13. He also spoke at the Convention of the Maine Telephone Association at Portland, his subject being, on both occasions, recent work and developments in the Laboratories.

Inspection Engineering

R. M. MOODY visited Hawthorne during the week of August 6 and O. S. Markuson visited Kearny during the week of August 13 for the regular Survey Conferences.

DURING THE WEEK of September 10, S. H. Anderson visited the Fort Wayne Plant of the General Electric Company to study the manufacture of regulated electric motors.

Outside Plant Development

C. H. KLEIN visited the plant of the Bethlehem Steel Company at Lebanon, Pennsylvania, during August to make studies on the development of pole-line hardware.

L. M. LINDENMUTH was in Norfolk, Virginia, on August 6 and 7 for the purpose of selecting samples for pole preservation studies.

Research

D. G. BLATTNER visited the Victor Talking Machine Company at Camden in connection with tests on the Orthophonic Victrola.

C. H. G. GRAY returned on August 20 from London and Paris. While in the latter city, he supervised the installation of the European master telephone transmission reference sys-

tem, a replica of the American system adopted as an international standard last year.

C. J. DAVISSON sailed on August 25 to attend a meeting of the British Association for Advancement of Science at Glasgow, Scotland.

C. W. BORGMANN AND E. G. MAYER attended a meeting of the American Chemical Society at Swampscott, Massachusetts.

H. H. LOWRY AND W. B. WARREN investigated grinding machinery at the Dorr Laboratories at Westport, Connecticut.

D. J. SALLEY visited New Brunswick, New Jersey, to observe a case of local action in the Philadelphia-New York cable.

A. C. WALKER AND E. J. ERNST investigated a humidity recorder for use in cable storage ovens at Kearny.

A. G. JENSEN left on August 28 for New Southgate, England, to resume his work on transatlantic radio telephony.

APPARATUS DEVELOPMENT

W. L. TIERNEY completed a survey for a 106-A (one kilowatt) equipment installation to be made for Taft and Wasmer, Inc., at Seattle.

R. E. MALLES visited Syracuse to inspect an installation of talking movies at Loew's Theatre.

R. E. KUEBLER, G. C. PORTER AND R. M. PEASE were in Albany from August 13 to 23 to install a Public-Address System for Governor Smith's notification ceremonies.

H. M. STOLLER visited Hawthorne in connection with control equipment for talking motion pictures.

J. R. TOWNSEND visited Hawthorne in connection with specifications for hardness limits of brass, nickel silver and phosphor bronze. He also visited the American Brass Company at Waterbury, Connecticut, to discuss Rockwell hardness-test blocks to be used in the preparation of these specifications.

H. C. CURL spent six weeks on the Pacific coast, where he tested and adjusted the general announcing systems of the U. S. S. "Lexington" and U. S. S. "Saratoga."

A. R. SAUNDERS made tests on contact resistances of 200-type selectors at exchanges in Albany, Schenectady and Syracuse.

SYSTEMS DEVELOPMENT

H. S. BLACK attended the Pacific Coast Convention of the A. I. E. E. at Spokane, Washington, where he delivered a paper on "Carrier-Telephone Systems for Short Toll Circuits" of which he is joint author with M. L. Almquist and L. M. Ilgenfritz of A. T. & T.

J. P. KINZER visited the repeater stations at Harrisburg, Reading and Allentown, Pennsylvania.

J. R. STONE visited the Fort Wayne factory of General Electric to witness tests on a new rating for commercial-type charging sets.

W. O. FULLERTON discussed the new 506-A private branch exchange with Stromberg-Carlson engineers at Rochester, New York.

C. E. HOKANSON spent several days at Hawthorne arranging for the initial installation of a new information desk at Cathedral central office, New York City.

R. P. JUTSON made tests on improved equipment for plate battery supply at Bluefield, West Virginia and Columbus, Ohio.

L. D. FRY AND E. J. KANE visited the new step-by-step central office at Atlantic City.

A Sensible Viewpoint on Insurance

Reprinted by permission from an article by Wallace Ames in Popular Science Monthly

"I'M GLAD I've got a good job," thought Warren Cady, as he stayed overtime at the office the afternoon of pay-day to go over his bills and draw checks to cover them.

Let's look over Warren's shoulder and see what his monthly crop of bills is. Here is the itemized list of the checks he drew:

Monthly mortgage and interest payment..	$83.33
Gas, electricity, milk, etc.	21.32
Mrs. Cady's monthly allowance	100.00
Mr. Cady's personal miscellaneous	50.00
Installment on automobile	41.20
Installment on radio	8.00
Installment on set of books	3.50
Installment on electric refrigerator	12.50
Total disbursements	$319.85

As Warren had deposited in the bank a salary check of $416.66 he had increased his bank balance $96.81 after paying the month's bills and drawing out the usual amount used by his wife and himself for current expenses. With a feeling of relief that an annoying job was attended to he pulled the day's sheet off his calendar pad as the last act before closing down his desk and starting for home.

Glancing at the notes on the calendar for the next day, Warren was reminded that his semi-annual premium payment on life insurance amounting to $60.00 was due. "Something is always taking the joy out of life," he burst out. "Just when I was enjoying the satisfaction of increasing my bank balance with a hundred dollars this insurance premium has to come due and eat up over half of it." After drawing another check Warren caught the 6:19 for home.

At the dinner table there was talk about their good friend and neighbor, Bill Kane, who had recently passed away, and speculation on what the future might hold for Mary and little Bill.

"That reminds me," said Warren to his wife, "I just paid our monthly bills today, and here is your check. What do you suppose you would do if I didn't come home once a month with a handful of shekels?"

Then, without waiting for the answer, for there was really no good answer to Warren's last question, he began to do a little figuring. He computed that there were seven more payments on the car, amounting to $288.40; four radio payments of $32; five book payments, $17.50 and six remaining refrigerator payments totalling $75.

Everything that the Cadys were buying "on time" was a sensible, worthwhile thing, from which they derived a lot of deserved satisfaction and pleasure. Nevertheless it worried Warren when he figured up a total of $412.90 that had to be paid before the auto, refrigerator, radio and books were really theirs.

But those items were only a drop in the bucket. There were the mortgages on the house. While it was a

good investment, something like $5,000 was still to be paid over a period of the next seven or eight years.

And then there was little Warren, Jr., their two-year-old son. They had spent many an hour talking and dreaming over his future. Of course they were planning to send him to college. And his daddy had visions of Junior making the football team.

"Yes," said Warren, at the close of the evening, "I'm glad I've got a good job—and my health."

"I saw Mary today," remarked Mrs. Cady, when she met her husband the next evening at the train. "She is a courageous soul and is bearing up better than I expected she would.

"While I was there the insurance man called. His visit was just like the silver lining, if there could be such a thing to the cloud that hangs over her just now. He was there to settle up three insurance policies and I was so pleased to learn how well fixed financially Mary is. Last night you remarked how good Bill had always been to Mary. I thought of what you said when the insurance representative was there.

"One policy for $2,000 was arranged to help put little Bill through college. That is still a long way ahead. That money invested will probably be more than enough. It will buy his clothes and take care of a lot of things while he is growing up.

"Another policy will pay Mary $5,000 right away. It will take care of her extra expenses at this time and pay off the mortgage on their home. So she hasn't got that to worry about. "From the third policy Mary will be paid $125 income every month. She is a good manager and can get along very comfortably on that amount. Bill sure was good to Mary."

"That was certainly far-sighted of Bill to carry all that insurance," said Warren, "But he must have had an awful time keeping up his premium payments. I find it a painful struggle keeping our $5,000 policy in force. Wonder how much he was paying out for insurance?"

"We manage to pay over $40 every month on our automobile," suggested Mrs. Cady.

"That's a thought," replied her husband. "Do you know, I never had the gumption to think of it that way. We readily pay for the car and the radio and the refrigerator because we are using them all the time, getting our pleasure out of them as we go along, and the necessary monthly payments seem even easier than the semi-annual insurance payments. My point of view has just been wrong.

"I think I will see my insurance agent tomorrow and work out a new program. Then I can quit worrying over what would happen to you if I should unexpectedly join Bill. We can extract enough money from our bank account to pay the initial premium. Before the next one comes due we will be through paying for the car and we can thereafter use that money to carry enough insurance to protect you against any financial hardships."

Warren Cady kept his good resolution. The next day he and his insurance agent* worked out a sound, practical program along these lines:

1. Warren Cady's present policy

** A similar service is available to all members of the Laboratories on application to Mr. L. H. Bunting, a specialist in life insurance. Mr. Bunting is to be found in Room 114 and is to be reached on Extension 264.*

was on the 20-payment life plan taken out 9 years before—when he was twenty-six years old. After deducting dividends, premiums on this policy were about $115.00 a year. When he reached age 46, he would cease paying premiums on this policy.

In the new program Warren's 20-payment life policy was left untouched to provide Mrs. Cady with $5,000 in cash to take care of current expenses, mortgages, etc. In insurance parlance this is referred to as a clean-up fund.

II. A $2,000 20-year endowment policy was arranged with his son as beneficiary.

It was planned to allow dividends to accumulate on this policy so that it would actually pay over $2,000 seventeen years hence. Thus in case Mr. Cady should survive the seventeen years, the insurance would provide cash for educational expenses. Provision was made whereby in the event of Mr. Cady's death before the endowment policy matured, the insurance company would hold the principal and pay interest to Mrs. Cady as guardian until the son was eighteen years old and then pay the principal to him in eight semi-annual installments. Thus, before and after entering college, funds would be provided for the boy's expenses.

III. Additional ordinary life policies aggregating $18,400 were taken out. These policies provided Mrs. Cady with a guaranteed income of $100 a month for twenty years after Mr. Cady's death. Together with the average excess interest paid the average total monthly income payments would be approximately $113.50. They also contained a clause whereby if Mrs. Cady should live more than twenty years after Mr. Cady's death, she would receive an income of $100 a month after the twentieth year.

IV. On all the insurance, except the $2,000 endowment, it was planned to use dividends to help pay premiums. These dividends would commence the second year of the new policies. Whereas the first year total premium payments would be $786, beginning the second year they would amount to only $654.

By taking out a number of small policies rather than one large one, Mr. Cady's insurance representative arranged it so that premium payments would come due monthly rather than in a large sum once or twice a year.* The average monthly premium payment beginning the second year was only about $55, in return for which Mrs. Cady was assured of $5,000 cash, plus $100 monthly income and Warren, Jr., was assured of $2,000 at age eighteen, plus income on that sum in the interval, subsequent to Mr. Cady's death.

When Mr. Cady reached age forty-six, he would cease paying premiums on his $5,000 20-payment life policy. Thereafter his monthly premiums would be reduced to an average of $40.

One of the most interesting things about Warren Cady's new insurance program was his point of view towards payments. Once he got the right idea he found that it was just as easy to pay $55 a month in insurance premiums as to pay a similar amount in installments on mortgages or merchandise.

**Members of the Laboratories may accomplish the same end even more conveniently by authorizing deductions from pay, the funds to be turned over directly to the insurance company.* *See* BELL LABORATORIES RECORD *for April,* 1928, *page* 246.

Club Notes

THE Nomination Committee of the Bell Laboratories Club will meet on Wednesday, October 24, to nominate candidates for the Club elections to be held on Monday, December 17. The offices to be filled for 1929 are as follows: President, First Vice-President, Second Vice-President, Departmental Representatives, two year term—Commercial Telephone Systems, Research, and Tube Shop. At least two but not more than three candidates are to be nominated for each office.

The Nominating Committee consists of the following members: D. A. Quarles, President; D. D. Haggerty, Secretary-Treasurer; Departmental Representatives: S. L. Stranahan, Apparatus Development; G. Rupp, Plant; P. J. Higgins, Tube Shop; T. C. Rice, Patent-Inspection Department; T. J. O'Neill, Systems Development; and J. C. Kennelty, Commercial.

Club members desiring to submit candidates' names to Departmental Representatives should do so before the meeting.

Basketball

The Bell Laboratories Club Interdepartmental League will start on Tuesday evening, October 30, at Labor Temple, Fourteenth Street and Second Avenue. Two games will be played every Tuesday evening with the first game starting promptly at 5:30 P.M. Eight teams representing the various major departments will take part in 1928-29 tournament. The departments represented are Plant, Research, Equipment, Drafting, Systems Engineering, Apparatus Development, Junior Assistants, Tube Shop, and Commercial.

Again this year the Club will enter a team in the Bell System Basketball League, the activities of which will start on Monday evening, November 12. Games will be played on Monday and Friday evenings in Stuyvesant High School and Wednesday evenings in Erasmus Hall High School, Brooklyn, during November, December and January. The team in the Bell System League will be managed by J. A. Waldron and the activities of the Interdepartmental League will be directed by C. F. Gittenberger. C. Maurer will referee the Interdepartmental games. These men can furnish further information regarding the tryouts for the league team and the practice preliminary to the Interdepartmental games which will be held on Tuesday and Thursday evenings during October with the exception of October 30.

Men's Bridge

The men's bridge club will begin its season on Monday, October 8, meeting in Rooms 275 and 277 at 6:00 P.M. After the brief preliminaries of organizing, with G. T. Lewis as director, the players will hold their first contest and will continue at the same place on Monday evenings until the middle of December. There will be two tournaments lasting ten weeks each, of which the

second will start in January, and in addition a match with players from 195 Broadway and a series of mixed games with players of the women's bridge club, to be scheduled definitely later. In all there will be about twenty-four meetings. Membership in the bridge group does not involve any pledge of attendance, but to be eligible for prizes in either tournament players must take part in at least eight of the ten meetings. Last year there were fifty-five names on the roster, with an average of nine tables at the weekly meetings. With a successful season as a background, more participants may be expected this year.

Dance

Arrangements for our first autumn dance have now been completed with the engagement of Hood's Orchestra. This group, general favorites among the Club members, have provided the music at many of our previous dances and entertainments.

Tickets are now available at the Club office and through departmental representatives. Only five hundred have been printed, since the attendance is limited to that figure by the hotel management. At our previous dances held at the McAlpin all tickets have usually been sold a week in advance, so that it is advisable to buy them early; in any case none will be on sale at the door. The tickets are $1.00 each, and the date is Friday, November 2. Dancing will commence at nine, and continue until two.

Club Orchestra

The symphony orchestra will hold its first rehearsal on Thursday evening, October 4. Plans are under way for engaging the services of a professional director. The orchestra is particularly in need of more string instruments and will be glad to welcome new candidates. The rehearsals will be held every Thursday evening at 6:00 P.M. in the Women's Rest Room on the 11th floor. For further information regarding these rehearsals, call D. D. Miller.

Hiking

For those who love the woods and mountains in their brilliant autumn colors, an attractive program of hikes has been prepared by A. Grendon and Phyllis Barton. Four expeditions have already returned to their base, reporting the strange manners and customs of the natives. and the hardships met and overcome in such far-away places as Bear Mountain and Kensico Quarry. Carrying their rations, two groups of intrepid explorers crossed the Hudson at Dyckman Street, and dispelling the darkness with camp-fires, held counsel as to an advance on Englewood or a retreat to the safety of Manhattan. A little-known section of Westchester County near Grassy Sprain Reservoir will be charted and photographed on Saturday, October 6, under the leadership of Miss Barton. On Sunday, October 21, the invaders will descend upon the country east of Boonton. After casting their ballots on Election Day, the hikers will meet at Dyckman Street Ferry and proceed to follow the shore to Alpine, where marshmallows and popcorn await.

Printed programs may be secured from Mr. Grendon or Miss Barton, who should be advised of your intention to accompany the expeditions.

Women's Basketball

Basketball starts Monday, October 15, and will continue on each Monday, from 5:30 to 7:30. St.

Luke's Court, conveniently located on Greenwich Street, just below Christopher Street, has been engaged for the home court of the team. During October, November and December, the sessions will be devoted to well-planned practices, tactics and rules of the game under the coaching of Charles F. Gittenberger, manager of men's basketball, with a view toward forming a well organized team to represent the Club in outside games during January, February and March. This activity is open to all women of the Laboratories regardless of experience, since plans have been arranged to take care of beginners as well as regular players. Marie Boman will manage women's basketball this year and it is requested that those interested enter their names with her.

SWIMMING

The fall swimming classes are now meeting regularly at the Carroll Club, Madison Avenue and 30th Street, on Monday nights from 7:00 to 7:30, and Wednesday nights from 5:30 to 6:00. Each class will cover a ten week period ending early in December, and will be held under the expert tutelage of Miss K. Spranger.

WOMEN'S BRIDGE

The Women's Bridge Club, meeting regularly on Tuesday nights, will hold its first meeting October 2, at 5:15 in the Rest Room on the eleventh floor. The Club will conduct another tournament for which prizes will be awarded. Katherine Munn is arranging for the meetings of the Club and would like to know in advance the names of those planning to attend.

DANCING

Another Dancing Class will be formed under the direction of Mr. Vecchio at the Vecchio Studio, 1160 Broadway. This course covers exercises for limbering and stretching, group and individual dancing and musical comedy steps. The class will be held on Friday evenings starting October 19 from 5:30 to 7:00, to continue for ten lessons, at a cost of five dollars. The class is limited to twenty-five members. Further particulars may be obtained from Harriet Newman, Extension 673.

Club Calendar for October

MONDAY, 1: Women's Swimming Class, Carroll Club, 7:00

TUESDAY, 2: Basketball, Men, Labor Temple, 5:30

Bridge, Women, Rest Room, 5:10

WEDNESDAY, 3: Women's Swimming Class, Carroll Club, 5:30

THURSDAY, 4: Orchestra Rehearsal, Rest Room, 6:00

Basketball, Men, Labor Temple, 5.30

FRIDAY, 5: Bowling, Men, Dwyers Manhattan Alleys, 5.45

SATURDAY, 6: Hike to Grassy Sprain.

Tennis Tournament, Doubles Championship, Mammoth Courts, Brooklyn, 2:00

MONDAY, 8: Women's Swimming Class, Carroll Club, 7:00

Bridge, Men, Rooms 275 & 277, 6:00

TUESDAY, 9: Basketball, Men, Labor Temple, 5:30

Bridge, Women, Rest Room, 5:10

WEDNESDAY, 10: Women's Swimming Class, Carroll Club, 5:30

THURSDAY, 11: Orchestra Rehearsal, Rest Room, 6:00

Basketball, Men, Labor Temple, 5:30

SATURDAY, 13: Tennis Tournament, Doubles Championship, Mammoth Courts, Brooklyn, 2:00

MONDAY, 15: Women's Swimming Class, Carroll Club, 7:00

Bridge, Men, Rooms 275 & 277, 6:00

Basketball, Women, St. Lukes Gymnasium, 5:30

TUESDAY, 16: Basketball, Men, Labor Temple, 5:30

Bridge, Women, Rest Room, 5:10

WEDNESDAY, 17: Women's Swimming Class, Carroll Club, 5:30

Glee Club Rehearsal, Rest Room, 5:10

THURSDAY, 18: Orchestra Rehearsal, Rest Room, 6:00

Basketball, Men, Labor Temple, 5:30

FRIDAY, 19: Bowling, Men, Dwyers Manhattan Alleys, 5:45

Athletic Dancing Class, Louis Vecchio Studio, 5:30

SUNDAY, 21: Hike, Lincoln Park to Towaco

MONDAY, 22: Women's Swimming Class, Carroll Club, 7:00

Basketball, Women, St. Luke's Gymnasium, 5:30

Basketball, Men, Stuyvesant High School, 6:00

Bridge, Men, Rooms 275 & 277, 6:00

TUESDAY, 23: Basketball, Men, Labor Temple, 5:30

Bridge, Women, Rest Room, 5:10

WEDNESDAY, 24: Women's Swimming Class, Carroll Club, 5:30

Glee Club, Rest Room, 5:10

THURSDAY, 25: Orchestra Rehearsal, Rest Room, 6:00

Basketball, Men, Labor Temple, 5:30

FRIDAY, 26: Bowling, Men, Dwyers Manhattan Alleys, 5:45

Athletic Dancing Class, Louis Vecchio Studio, 5:30

MONDAY, 29: Bridge, Men, Rooms 275 & 277, 6:00

Basketball, Men, Stuyvesant High School, 6:00

Women's Swimming Class, Carroll Club, 7:00

Basketball, Women, St. Luke's Gymnasium, 5:30

TUESDAY, 30: Basketball, Men, Labor Temple, 5:30

Bridge, Women, Rest Room, 5:10

WEDNESDAY, 31: Women's Swimming Class, Carroll Club, 5:30

Glee Club, Rest Room, 5:10

BELL LABORATORIES RECORD

SYNCHRONIZED REPRODUCTION OF SOUND AND SCENE

NOVEMBER 1928 Vol. 7 No. 3

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Bell Laboratories Record

A Monthly Magazine of Information for Members of
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Bell Laboratories Record

Volume Seven NOVEMBER, 1928 *Number Three*

Reproducing Sound and Scene

Theatrical audiences throughout the United States have been enjoying for many months audible motion-pictures, recorded and reproduced by methods and apparatus developed in Bell Telephone Laboratories and made available to producers and exhibitors by Electrical Research Products, Incorporated. A furor has arisen in the theatrical and motion-picture professions, excited by the wondrous possibilities and amplified by public demand and interest.

Relating to this new art of talking motion-pictures much has already been published, for it is based upon years of telephonic research in speech and hearing, the conversion of energy between acoustic and electrical systems, and electrical methods for recording, amplifying and reproducing sound.

Publication of the technical processes involved, however, is following the actual accomplishment in accordance with the tradition of the Laboratories that demonstration shall precede exposition and the hazard of prophesy be avoided.

During September a series of papers was presented to the Society of Motion Picture Engineers by members of the technical staff of the Laboratories. These dealt with the fundamental principles of synchronized recording and reproducing of sound and scene, and with some of the apparatus developments of the Laboratories in that field.

In this issue of BELL LABORATORIES RECORD the authors of those technical papers present in a series of articles the substance of their original expositions.

Contents

Fundamentals of Speech, Hearing and Music

By JOHN C. STEINBERG
Research Department

SOUND-PICTURES unite two long lines of development: one of the recording and reproduction of sound, affecting the sense of hearing; the other of the recording and reproduction of visual objects, affecting the sense of sight. The success attained in these lines has been largely due to research continually carried on in the fundamental facts of each and to the perfection of apparatus modified with each advance in knowledge.

The present paper briefly recounts some of the outstanding facts of the science of sound as it affects the development of the sound-picture. It compasses in reality five sub-sciences: one pertaining to hearing, the sense organ on which all perception of sound depends, two covering speech and music, the types of sound most commonly reproduced, and two covering musical instruments and the voice, the generators of the two main classes of sounds.

Speech is produced by streams of air forced out through the vocal passages by the lungs. The trachea or wind pipe is terminated at the upper end by the larynx which contains two muscular ledges, known as the vocal cords, forming a straight slit through which the air stream passes. During speech these cords vibrate so that the slit is alternately opened and closed and by this action a train of sound waves is set up in the lower part of the throat. As these waves pass out into the air, certain resonant and transient characteristics are impressed upon them by the vocal cavities and the movements of the tongue and lips, and it is these variations that are interpreted as speech.

All speech sounds are produced in this manner, except those symbolized by the letters p, k, t, f, s, ch, sh, and th (as in thin). These, called unvoiced sounds because the vocal cords play no part in their production, are

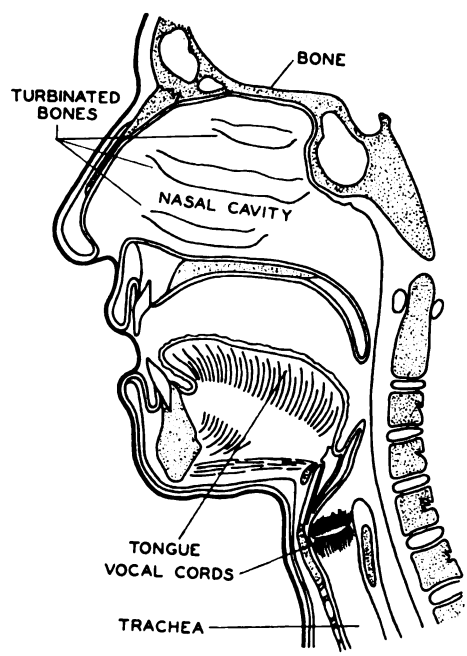


Fig. 1—A cross-section of the human head showing relative positions of the vocal organs.

produced by frictional vibration set up in the mouth itself. Both voiced and unvoiced sounds may be divided into two classes: those produced by a continuous flow of air, called the con-

tinuants, and those produced by the sudden stoppage of the air, called the stops. In the former class are such sounds as a, v, and f, and in the latter class such sounds as p, g, d, and t.

Although the vocal cords lend quality to the voice they do not give, to any great degree, the distinguishing characteristics of the speech

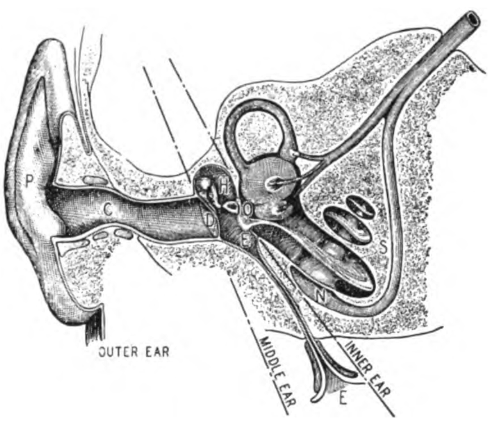


Fig. 2—A cross-section of the ear canal can only suggest its complex structure.

sounds. These are produced mainly by the mouth and nose cavities, as is evidenced by the fact that we can understand whispered speech, in which the vocal cords play no part. As a matter of fact counterparts of the lungs and vocal cords can be located quite outside the body and still produce intelligible speech. This is actually accomplished by the artificial larynx, a piece of apparatus developed by Bell Telephone Laboratories for those who have undergone an operation known as tracheotomy, in which the larynx is removed and the wind pipe is terminated by a small hole in the patient's neck, through which he breathes.

The mechanism of hearing may be divided into three parts: the outer, the middle, and the inner ear. The outer ear, consisting of the external parts and the ear canal, terminates at the drum. The middle ear contains three small bones, the hammer, anvil, and stirrup, which connect the drum with the small window or diaphragm, "O," of the inner ear. The inner ear is a spiral cavity, "S," in the bone, which is filled with liquid, and into it, as may be seen from the illustration, projects a spiral ledge. The liquid above this ledge is separated from that below it by a flexible membrane along which are distributed the nerves of hearing. Two windows, "O" and "E", retain the liquid at the base but at the apex there is a small hole through the membrane which allows liquid to flow from the upper side to the lower.

Sound enters the ear as successions of minute changes in the air pressure which are known as sound waves. These cause the ear drum to vibrate, and it is supposed that the liquid in the inner ear vibrates similarly, affecting the central membrane in different positions depending upon the frequency—the high tones disturbing one end of the membrane and the low tones disturbing the other end. This membrane may be compared to the keyboard of a player piano in operation, the keys at different parts of the scale being disturbed successively with the progress of the music. With the ear the pattern of the disturbance on the membrane is carried to the brain and there interpreted as speech sounds.

The range of pressure and frequency that the ear can perceive is represented on Figure 3 where the scale of abscissas is frequencies in cycles per second, and the ordinate

scale is pressure in dynes. Frequencies above about 20,000 cycles are not perceived as sound nor are those below about 20. Any frequency between these limits, however, is recognized as sound if its pressure is above the lower boundary curve marked "Threshold of Audibility." The upper boundary, marked "Threshold of Feeling" indicates the pressure at which feeling begins. Above this line the sounds are felt, actually causing pain by their excessive pressure.

Frequency and pressure are only the physical characteristics of a sound; our mental responses are called pitch and loudness. Both of these vary logarithmically with their stimulus, difference in pitch between two sounds corresponding to the logarithm of the ratio of their frequencies, and similarly, differences in loudness are proportional to the logarithm of the difference in pressure, but with loudness the proportionality is not quite constant so that constant loudness lines are not truly horizontal. Because of this logarithmic law the illustration is plotted with logarithmic scales, and in addition an arbitrary loudness scale is shown on the right, the units of which, called sensation units, are defined as twenty times the logarithm of the pressure.

Studies on the wave forms of speech sounds have shown that the pitch of man's voice is of an order of 128 cycles per second, that of woman's voice of an order of 256 cycles, and with both, overtones of the fundamental cord tone occur. These studies have shown further that frequencies as high as 8000 or 9000 cycles exist in various speech sounds. Studies on the interpretation of speech sounds have indicated the presence of tones covering a large part of the audible frequency range. The location of the various parts of speech on the entire sound area is indicated in the illustration. Although in this figure the speech sounds have been grouped in sharply defined areas, actually the sounds overlap somewhat, and the indicated areas are those which are most important in the interpretation of the sounds. The three voiced consonants, symbolized by the letters v, z, and th (as in them), are exceptions and belong in the unvoiced consonant area.

In general, woman's speech is more difficult to interpret than man's, which may be due in part to the fact that woman's speech has only one-half as many tones as man's, so that the membrane of hearing is not disturbed in as many places. The greatest differences occur in the case of the more difficult consonant sounds which in woman's speech are not only fainter

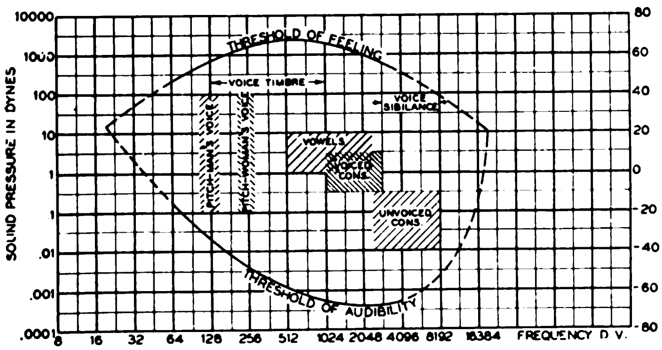


Fig. 3 — Any sound that can be heard lies within the field outlined here. Areas covered by the most prominent speech sounds are indicated.

but require a higher frequency range for interpretation. The range from 3000 to 6000 cycles for man's voice corresponds roughly to the range from 5000 to 8000 cycles for woman's voice and since the ear is less sensitive at these higher frequencies and the sounds are initially fainter, their difficulty of interpretation is

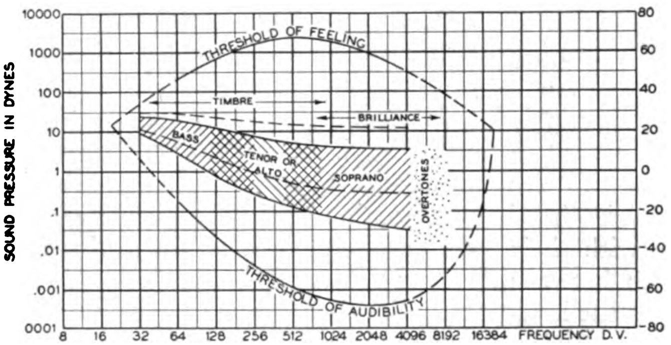


Fig. 4 — Constant loudness lines are not quite horizontal but slope down with increasing frequency as shown.

of course proportionately greater.

Musical sounds, like those of speech, consist of a fundamental frequency and various overtones, but unlike speech are sustained for appreciable lengths of time, and changes in them usually take place in definite steps, known as musical intervals. The frequencies that are present depend upon the type of instrument and the character of the music but the pitch of the tone is determined by the fundamental frequency which, however, need not be present in the musical tone, as the overtones, which are multiples of the fundamental, may cause the correct pitch sensation.

Musical instruments may be divided into two general classes, string instruments and wind instruments. Tones of string instruments, produced by plucking, striking, or bowing, are usually reenforced by resonating air cavities and sounding boards. Tones of wind instruments may be produced by the aid of reeds as with the clarinet or with the flute, or by the lips of the player acting as reeds, as with the horns. Each class may be further subdivided into melody and harmony instruments. In the former class only one note is usually produced at a time; in the latter class several notes are usually produced simultaneously. In general, harmony instruments are capable of producing notes over a much wider frequency range than melody instruments and a given type of instrument of the latter class may, therefore, include several instruments each covering different frequency ranges, such as the bass, tenor, and alto trombone.

Experiments have indicated that notes of different frequency or pitch as produced by a musical instrument appear about equally loud to the ear, which might be expected as the ear has played an important part in their design. In Figure 4 contour lines of equal loudness are shown for the frequency range from 32 to 4000 cycles, which has been divided into three parts, the bass, tenor or alto, and soprano registers, corresponding to the notes produced by various instruments. The contour lines indicate that the notes of the lower registers have greater sound pressures than those of the higher. The range of pressures for various instruments, however, is smaller for low notes, as has been determined by direct measurements of the pressures produced

when played by musicians. Contour lines for loud tones show a smaller change in pressure in going from low to high notes than do the contour lines for faint tones so that it would seem that music played faintly would cover a greater pressure range than loud music.

Percussion instruments such as drums and the various accessory traps produce the greatest pressures that are used in music and although the fundamental frequency of the notes which they emit is fairly low, the complete notes are particularly rich in tones of higher frequency, extending as high as 10,000 cycles. Although these higher tones die out rather rapidly, they are essential to good definition.

The organ, the piano, and the harp have the greatest span, covering a frequency range from about 16 to 4000 cycles. All three of these instruments are characterized by a rather prominent first overtone, so that their effective range extends as high as 8000 cycles.

Melody instruments, owing to their limited range, are among the easiest to reproduce. In any given register, wind instruments produce greater intensities than string instruments, of which the violin produces the faintest sounds. As a class these instruments produce notes covering the frequency range of 32 to 4000 cycles.

From the auditory sensation area, we have seen that the ear is able to perceive a large number of tones of different intensity and frequency. We have also seen that the voice and various musical instruments produce tones which cover a large portion of the auditory sensation area. In order to obtain information as to the relative importance of various parts of this area to the sensory characteristics of speech and music, experiments have been performed in which the tones falling in various parts have been eliminated from the sounds by means of filters.

When frequencies below 100, 200, 300, or on up to 1000 cycles are progressively eliminated from speech, its character changes markedly, the terms "timbre" or "tone color" best describing the characteristic lost. This characteristic appears to be associated with the fundamental and the first few overtones of the voiced sounds and their presence is necessary, therefore, in order to convey this quality, but for the correct interpretation of the speech sounds frequencies below 300 cycles do not appear to be essential.

When frequencies above 8000, 7000, or on down to 3000 cycles are eliminated, the character of the speech again changes markedly; the term "sibilance", appearing to describe best the characteristic lost, refers to the prominence of the hissing or frictional character of speech. If attention is directed to such sounds as s, f, th, and z, the elimination of frequencies above 6000 or 7000 cycles is readily detectable, but it requires rather close attention to detect the elimination of frequencies above 8000 cycles. Elimination of frequencies above 7000 cycles, however, slightly impairs the interpretation of the s and z sounds of woman's voice and elimination of frequencies above 6000 cycles those of the f and th sounds of man's voice, and of the f, th, s, and z sounds of woman's voice. The impairment due to eliminating higher frequencies is usually greater in the case of female voices.

As with speech, the tone color or

timbre of musical tones also appears to be associated with the fundamental and the first few overtones of the note produced. Timbre is probably more important in music than in speech as it is one of the things that distinguish the tones of various instruments. In general, the fundamental and the first three or four overtones are necessary in order to distinguish the tones of various instruments. When overtones higher than these are eliminated the tones lose a characteristic best described by the terms "brilliance" or "definition"; they seem to lose life and become dull. The prominence of these characteristics varies with the type of instrument, the composition of the music, and the personality of the musician.

The notes which are used most in music are contained in the octaves below and above middle C, or from 128 to 512 cycles, and as the fourth overtone of 512 cycles has a vibration frequency of 8192 cycles, tones of this frequency and below occur frequently in music. A trained ear could no doubt detect the elimination of frequencies above this range from the ordinary run of music, but the average individual would have difficulty in detecting the elimination of frequencies above even 6000 or 7000 cycles, unless he gave particularly close attention to the percussion instruments.

Another phenomenon of hearing which enters into the sensation of sound is called masking. Lower pitched tones in a sound deafen the auditor to the higher tones, and this deafening or masking effect becomes very marked when the sound pressures of the lower tones are greater than twenty sensation units. The optimum loudness for the interpretation of speech corresponds to a sound pressure between 0 and 20 sensation units. If the sound pressure is less than this the fainter sounds are inaudible while if it is greater, the masking effect impairs the interpretation. When sounds are increased in loudness the lower registers are accentuated because of this masking effect so that for most faithful reproduction sounds should be reproduced with about the same loudness as the original sounds.

General Principles of Sound Recording

By EDWARD C. WENTE
Research Department

THAT sound is perceived by the ear as the result of a disturbance in the air was known to the ancient Greeks, and that objects are set in vibration by intense sounds must have been observed by primitive man, but it was not until 1857, or less than a century ago, that the first instrument was constructed for making a graphical record of sound waves. In that year Léon Scott patented in France an instrument (Figure 1) which he called the phonautograph. A piece of smoked paper was attached to the cylindrical surface of a drum, so mounted that when rotated by hand it moved forward at the same time. A stylus was attached to the center of a diaphragm through a system of levers in such a manner that it moved laterally along the surface of the cylinder when the diaphragm vibrated. Over the diaphragm was placed a barrel-shaped mouthpiece. When the drum was rotated, words spoken into the mouthpiece caused the stylus to trace a wavy line upon the smoked paper. This wavy line was the first known record of sound vibrations.

It was twenty years later, in 1877, that Edison brought out an epoch-making invention. He constructed a machine very similar to the phonautograph but differing in two important details. The smoked paper was replaced by a sheet of tinfoil, and the stylus was attached directly to the diaphragm so that it traced an impression of variable depth, as the diaphragm vibrated, instead of a wavy line as with the phonautograph. After such a record had been made the drum was returned to the starting point and, with the stylus in place, again rotated as before. The recorded sound was then intelligibly reproduced. Thus Edison gave us the first phonograph.

In subsequent models the tinfoil was replaced by a wax cylinder. For many years the wax record, either in cylinder or disc form, was used almost exclusively for the recording and reproducing of sound. Although many other methods of recording have been suggested, it is only in the last few years that records made photographically have come into the

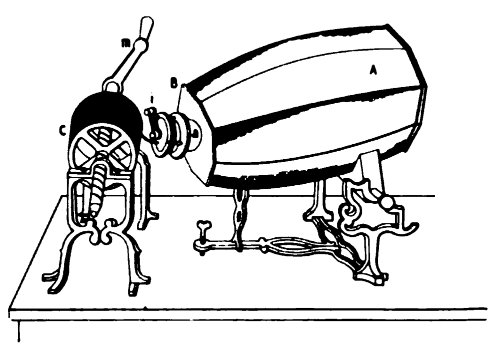


Fig. 1 — *Sound was first recorded on the phonautograph of Léon Scott.*

commercial field as competitors. At the present time both the wax and the photographic records are used in conjunction with motion pictures.

Photographic records are now being made by many different types of apparatus, but they may be divided

into two general classes. In one of these, the record is a trace of constant photographic density but of variable width, while in the other the width is constant but the density varies. In one or two proposed methods the record is a combination of both types.

Almost all systems experimented with today have at least one element in common with the phonautograph: a diaphragm that is set in vibration by the sound to be recorded. The diaphragm may be mechanically connected to the engraving mechanism or recorder as in the phonautograph, or, it may be electrically connected as in most modern systems. In practically all systems the diaphragm forms an essential element.

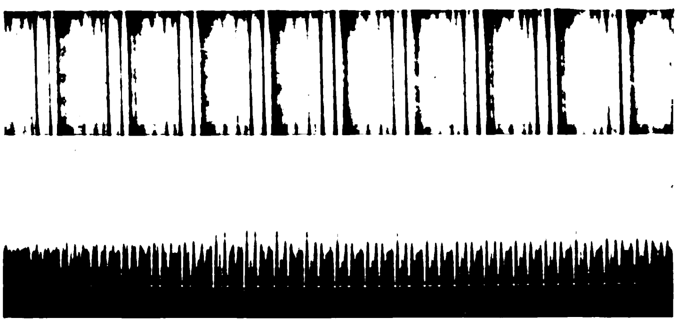


Fig. 2—Photographic records of sound may be either of constant width and varying density, shown above, or of constant density and varying width, show below.

Unfortunately a diaphragm does not in general have the same response at all frequencies. A favorite experiment in lectures on elementary physics is to sound a tuning fork and with it, through the air, set in vibration a second tuning fork. In this experiment it is important that the pitch, or the resonant frequency, of the two forks be very nearly the same, or the motion set up in the second fork will be too small to be observable. Diaphragms, and in fact almost any other type of mechanical system, will have at least one resonant frequency, which means that, under the action of sound waves, the response will be much greater at this frequency than at any other.

In the older methods of recording resonance was purposely introduced in order to obtain records of sufficient amplitude. The frequencies lying in the resonance region were then much over-emphasized. The sound reproduced from such records had a blasting and metallic quality, and well deserved the title "canned music."

Because of the complex nature of speech and music and of the great amount of distortion introduced by the early recorders and reproducers, the surprising thing is not that the quality of reproduction was poor, but that the reproduced sounds were at all intelligible. In fact it has been suggested that the invention of the telephone, which preceded the phonograph, might have been delayed for many years had the complex nature of speech sounds been generally known at the time, since its inventor probably would have dismissed his ideas as altogether impracticable.

Although considerable distortion may be introduced by the recording and reproducing systems before the character of the sounds is so changed that they can no longer be recognized, the amount of distortion must be kept extremely small, if all classes of sounds are to be reproduced to such a degree of fidelity that the ear cannot distinguished them from the orig-

inal. It is necessary, therefore, to diminish the distortion by the diaphragm to a negligible value.

The electrical method of recording, which is today widely used in the production of commercial sound records, has been developed primarily so that a diaphragm giving a uniform response may be used and at the same time a record of sufficient amplitude be obtained. In the modern method the pick-up diaphragm is made a component part of the recording microphone. Here a small amplitude of motion will serve, as the voltage generated may be amplified to an amount sufficient for operating a rugged and distortionless recorder. A comparison of the diaphragm in the Edison recorder with that of the microphone used in the majority of present recording systems is interesting. In the former the maximum amplitude required for the loudest sounds is about 0.001 inch, whereas in the latter under ordinary recording conditions it is only about one-tenth of this amount, and the weight of the microphone diaphragm is only one-twentieth as great as that of the Edison recorder. It can thus be seen how the problem of design of a pick-up diaphragm is greatly simplified in the electrical method.

It is important, of course, that the rest of the recording system shall also be free from distortion. If a microphone of uniform response is available, however, the design of a distortionless recorder is made comparatively easy, for its sensitivity may to a large extent be disregarded, as the required power can be obtained by vacuum-tube amplifiers. In the electrical method, extraordinary improvements have been made over the older systems in elimination of distortion.

The problem of developing recording apparatus is in many respects identical with that of developing high quality radio transmitters. With recording apparatus, however, there is the additional problem of distortion introduced by the record itself. If, for instance, a record is run at a speed of ten inches per second, and a tone having a frequency of 5,000 cycles per second is recorded, the length of one cycle on the record will cover a distance of only 0.002 inch. In the case of wax records the needle must have a very fine point; and in the photographic record the width of the light beam as measured along the direction of motion of the film must be extremely small. At whatever speed the record may be driven, there will always be some frequency beyond which all tones will become more and more attenuated. Although the loss of the higher frequencies does not

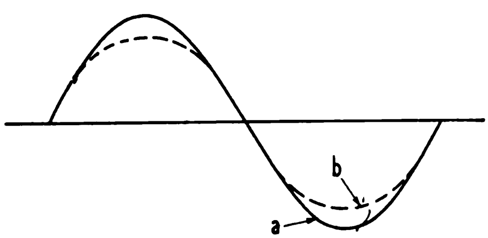


Fig. 3—Non-linear distortion changes the shape of a sine wave form from "a" to the flatter top type of "b".

impair the tone quality as much as does the presence of sharp resonance regions, yet it reduces the intelligibility of speech and the richness and brilliancy of musical sounds.

There is another type of distortion commonly present in reproduced sound, which is frequently designated non-linear distortion. It is introduced when the response of any element of the system is not proportional to the stimulus. A pure tone, for example,

of sine wave form, as shown in "a" of Figure 3, may be reproduced so as to have a wave form like that of "b". Distortion of the wave form in this manner is equivalent to the introduction of extraneous frequencies. If the magnitude of these added frequencies is too great, the tone quality will be very disagreeable. A small amount of distortion of this kind, however, is not noticeable, because the primary tone will mask the extraneous one. It is a well known fact that a tone must be much more intense to be heard if another, and particularly a lower, tone is sounded simultaneously.

A type of distortion peculiar to recording is that introduced by a non-uniform speed of the medium on which the record is being engraved. This may not always be serious, but in certain cases of sustained tones, speed variations cause a disagreeable flutter and in some types of music a decided harshness of tone.

One of the most serious problems with which the radio engineer has to contend is static interference. This also has its counterpart in sound reproduction from records. As the ether through which the radio waves are sent is non-homogeneous because of extraneous electrical disturbances, so the sound record is non-homogeneous on account of the non-uniformity of the material on which it is engraved. The noise resulting from these irregularities is often designated as surface noise. With the wax record, most of this noise has its origin in the minute irregularies of the material and with the photographic record, in the finite size of the grains forming the photographic image.

The difficulties of eliminating this noise arise from the fact that the physical intensity of audible sounds covers an exceedingly wide range. The ratio of pressures of the maximum to the minimum is about ten million. If a record of this extreme range of volume were to be recorded the amplitude of the loudest tone would have to be ten million times as great as for the faintest tone. There is a maximum amplitude that a record can accommodate, which in the case of the wax record is about 0.002 inch. If a tone having an intensity near the maximum level is recorded at this amplitude, the amplitude of a tone just audible would be only 0.000,000,000,2 inch. It is difficult to get a material having a degree of homogeneity corresponding to this value.

A similar condition exists with photographic records where the pattern is formed by grains in the emulsion which have a magnitude somewhat less than 0.000,05 inch, depending upon the type of emulsion used. The range of volume considered here is extreme, of course, and in practice it is not necessary to record a range of this extent, but it serves to illustrate the extraordinary requirements placed upon the recording medium. When the range of frequencies that are to be reproduced is increased, the surface noise effect becomes greater. As in the case of the different types of distortion discussed above, the difficulties to be met are increased as the quality of reproduction is improved.

Recent Advances in Wax Recording

By HALSEY A. FREDERICK
Research Department

SUCCESS of recording and reproduction of sound by the so-called "electric" method with a disc record may be considered as depending on several factors. In order, these are: the studio, with its acoustic conditions; the microphone; the amplifier; the electro-mechanical recorder; the "wax" record; the copying apparatus and procedure; the hard record, or "pressing"; the electric pick-up; the amplifier; the loud speaker; the auditorium. The chief problem is that of making the speech or music reproduced in the auditorium a faithful duplicate of the original sounds, using this chain of apparatus. Cost, reliability, and the time required for the process of recording are among a number of other considerations, but these are all subordinate to the problem of fidelity. While it may be convenient or even necessary to introduce distortion into certain of the steps to compensate for such distortion as may be unavoidable in others, experience shows that it is desirable for the sake of simplicity, reliability and flexibility to reduce such corrective warping to a minimum, and to make each step in the process as nearly perfect as possible.

Perfection of a complete recording and reproducing system may be judged by the practical method of listening to the overall result. Each element of the system must be analyzed thoroughly, however, if outstanding excellence is to be attained. One of the most useful of the means of analysis is study of the response-frequency curve. In order that all frequencies be reproduced equally and that the ordinary faults of resonance be avoided, this curve must be flat and, particularly, free from sharp peaks. Good reproduction requires that frequencies from 50 to 5,000 cycles be included without discrimination. If however frequencies down to 25 or 30 cycles be included, a noticeable improvement will be obtained with some classes of music, while if the upper limit be increased to 8,000 or even 10,000 cycles, the naturalness and smoothness of practically all classes of reproduction will be noticeably improved.

A second important criterion of any system is that the ratio of output to input shall not vary over the range of currents or loudnesses from the minimum up to the maximum used. If this requirement be not met, sounds or frequencies not present in the original will appear in the reproduction. This is the type of distortion commonly produced by an overloaded vacuum-tube amplifier; it is often called non-linear distortion.

A third requirement not entirely dissociated from the first two is that any shifts in the phase relations shall be proportional to frequency.

Since our standards of perfection in sound-reproducing systems are growing constantly more exacting, over-all results that seemed excellent a short time ago are only fair to-

day, and before long may seem intolerable. It has, therefore, been necessary for the analysis of each step of the system to be constantly more searching and fundamental.

Of the eleven links in the chain of apparatus for electrical recording and reproduction, only five are peculiar to the wax method. These are the electro-mechanical recorder, the wax record, the copying apparatus, the "pressing," and the pick-up or reproducer. The extent to which the wax method is capable of the highest quality of reproduction will be disclosed by an examination of these five links. Any consideration of the practical advantages or disadvantages of the method can logically follow this examination into the quality possibilities. The considerations which follow refer to the so-called lateral-cut records, in which the grooves are of constant depth and oscillate or undulate in each case about a smooth spiral. This type of record is used in the Western Electric Company method of synchronized motion pictures which uses disc records. Some, but not all, of the considerations might apply to "hill and dale" records, but the characteristics of these records will not be discussed.

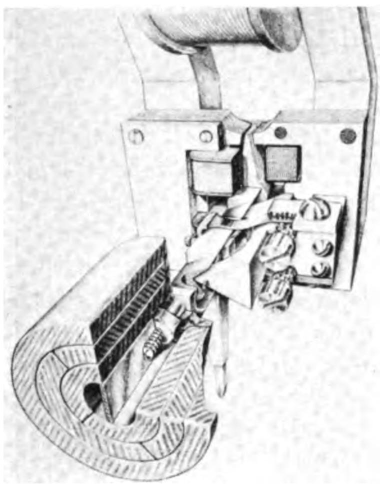


Fig. 1—Section of electrical recorder.

The first piece of apparatus in the chain unique to the wax process is the electro-mechanical recorder, whose function is to receive power from the amplifier, and with it drive a mechanical recording stylus. The present-day recorder is a highly developed apparatus based on extensive experimental as well as theoretical studies. Recorders which have been supplied by the Western Electric Company have been designed to operate over a range of frequencies from 30 to 5,500 cycles. The device operates in linear fashion over the range of amplitudes involved in speech and music. As is seen in Figure 2, the response falls off below about 250 cycles. This falling characteristic is necessary in order that the maximum loudness be obtained from a record for a given spacing between grooves without cutting over from groove to groove. A characteristic of the pickup is that the voltage induced in its windings is proportional to the velocity with which the armature moves. In order therefore that a lateral oscillation of the needle point may furnish constant output voltage, it is necessary that the lateral velocity of the needle point be constant. For a sine wave, velocity is proportional to the product of amplitude and frequency, so that as frequency increases, amplitude must decrease proportionately. With the characteristic shown with these recorders, constant velocity is obtained from about 250 cycles to 5,500 cycles. Below 250 cycles an approximately constant amplitude is obtained. If,

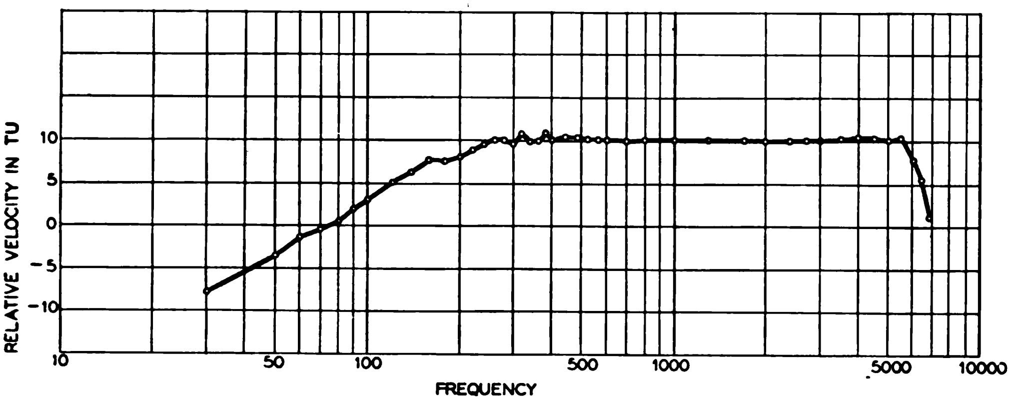


Fig. 2—Typical frequency characteristic of a commercial recorder.

therefore, sounds of constant absolute intensity are to be recorded over this range of 30 to 250 cycles, there is equal tendency for sounds of the different frequencies in this range to over-cut the record groove. Attenuation of the lower frequencies by the recording apparatus may be corrected in reproduction by a suitable electric network. Such a network will increase the subsequent amplification required but, as this additional amplification occurs in the first stages, it is not expensive. Practically it has not been found necessary or desirable to introduce such a corrective network since the correction has been largely cared for by the characteristics of the pickups which are used.

Recent development studies have established the possibility of flattening the response at the low-frequency end and of raising the high frequency cut-off of the recorder. The characteristic obtained with a laboratory model shows uniform performance within ± 1 TU from 250 to 7,500 cycles and within ± 4 TU from 30 to 8,000 cycles. Although its immediate practical value may be limited by other portions of the system, this device is of great interest in that it establishes beyond question the fact that an extremely broad range of frequencies can be successfully recorded in the wax.

The broad, flat characteristic obtained with electric recorders has

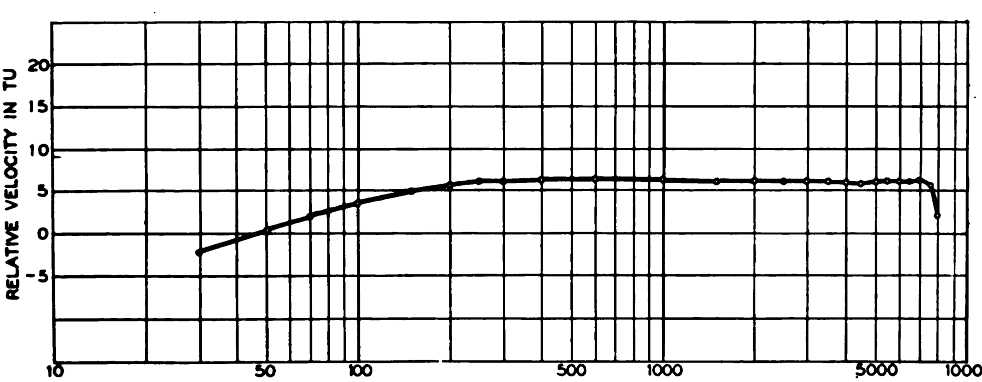


Fig. 3—Frequency characteristic of a recent laboratory recorder.

been made possible by so designing their elements that they constitute correctly designed transmission systems. In such a transmission system, whether it be an electrical recorder or a long telephone line, a correct terminating impedance is required. The load imposed by the wax is somewhat variable but fortunately is rather small. It has been found desirable to make the other impedances in the recorder relatively large so as to dominate the system and thus minimize the effects of any changes in the impedance imposed on the stylus by the wax. The mechanical load used as a terminating impedance and to control the device has consisted of a rod of gum rubber ten inches long.

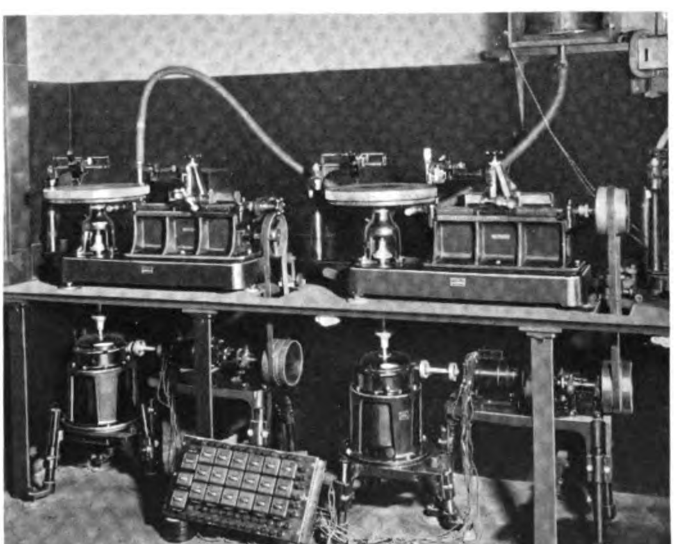


Fig. 4—Two recording machines arranged to be driven synchronously with cameras.

Torsional vibrations are transmitted along this rod at about one hundred feet per second so that its length is equivalent to an ideal electrical line of about 1,500 miles. Loss of energy along this rubber rod is such that a vibration is substantially dissipated by the time it has travelled down the line and back. Thus the rod constitutes a substantially pure mechanical resistance, whose magnitude is approximately 2,500 mechanical abohms, referred to the stylus point as its point of application.

In recording, the usual procedure is to use a disc from one inch to two inches thick and from thirteen to seventeen inches in diameter, composed of a metallic soap to which small amounts of various substances have been added to improve the texture. This disc, commonly called a "wax," is shaved to a highly polished surface on a lathe, and then is placed in a recording machine, essentially a high-grade lathe by which the wax is rotated at a very uniform rate and in definite relation to the film with which it is being synchronized. The recorder with its cutting tool is moved radially across the surface of the disc, common phonograph procedure being to record from the outer edge of the disc toward the center, whereas with records for Western Electric sound pictures the direction of cutting is reversed. After a record has been cut the wax may be handled, and with proper precautions may be shipped from place to place.

The shape of the groove varies somewhat in commercial practice. That used in records for Western Electric apparatus is approximately

0.006 inch wide and 0.0025 inch deep, and the pitch of the spiral is between 0.010 and 0.011 inch, so that the space between the edges of the grooves is about 0.004 inch. Thus the maximum safe amplitude is about 0.002 inch. If this is reached at 250 cycles the corresponding amplitude at 5,000 cycles, assuming that the sound is constant in absolute intensity over the intervening range, will be only 0.0001 inch.

In the records used with Western Electric apparatus the linear speed of the groove past the reproducer point ranges from 140 feet per minute, at the outside of the spiral, to 70 feet per minute at the inside. The rate of rotation is dependent upon the outer diameter of the grooves which is determined primarily by the length of time to be covered by a single disc. When the minimum linear speed and the groove spacing are decided upon, there is an optimum relation between the size of the record, the rate of rotation and the playing time.

Since any roughness in the walls of the groove introduces extraneous noise in the reproduced sound, it is important that the groove be kept truly smooth. Before starting, the surface of the disc must be shaved to a high polish, and the texture must be fine and homogeneous. Not only must the composition be correct, but the proper temperature must be maintained during recording. Waxes may be obtained commercially whose texture is satisfactory over the ordinary range of room temperatures. The disc must be levelled in the recording machine with reasonable care, and the stylus must be sharp and of a shape to insure a clean cut. The wax shaving is removed as cut by air suction. To aid in maintaining the cut at the correct depth there is a so-called advance ball which rides lightly on the surface, supporting the stylus at the proper height in spite of small inaccuracies in levelling the disc or deviations from planeness. For adjusting the advance ball with respect to the stylus, the groove is observed with a calibrated microscope. Maintenance of the necessary adjustments and satisfactory operation of the recording machine requires an ordinarily skilled mechanic with reasonable experience.

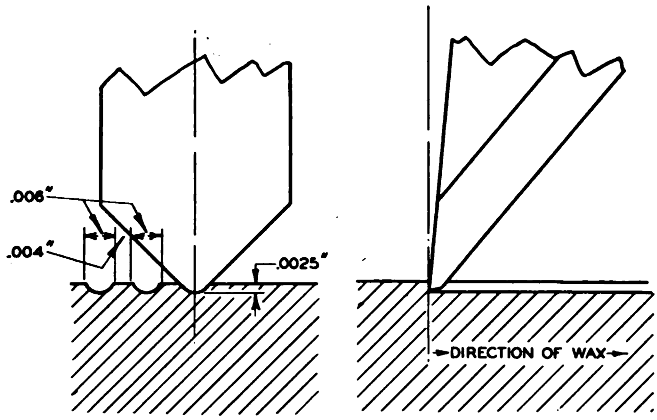


Fig. 5—Details of the stylus point of the recorder. Left, a radial section through the wax; right, a section looking from the stylus point to the center of the disc.

After a record has been cut, the sound may be reproduced directly from the wax by means of a suitable pick-up or reproducer. Ordinary reproducers rest much too heavily on the records to be used on wax; the vertical pressure between needle point and record in an ordinary phonograph is of the order of 50,000

pounds per square inch. Obviously any such pressures would destroy a groove in the wax.

These high pressures have been necessary in order that the groove might drive the needle point of the reproducer properly; their reduction requires reduction of the impedance offered by the needle point to transverse vibration. Such reduction of the impedance of a "playback" mechanism requires that both its mass and its stiffness be cut down to a minimum. That now available has been designed with those requirements in view, and represents a large advance toward ideal reproduction. Whereas playbacks formerly in use failed to reproduce the higher and lower frequencies with much satisfaction, response of the new piece of apparatus is not widely different from that obtained from finished records with the best electric pick-ups now available. The response is sufficiently good to serve as a most valuable criterion in judging the quality of a record immediately after recording. At the same time, a record may be played a number of times without great injury. At low frequencies there is little change and at the higher frequencies a loss of about 2TU per playing. The opportunity thus made available for an artist to hear and criticize the results of his efforts, immediately at the end of his performance, can hardly be overestimated in its value to studio and recording operation.

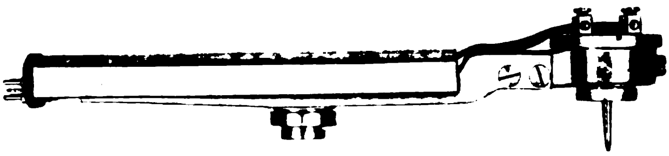


Fig. 6—Playback for reproduction directly from wax discs.

After a groove has been cut into the wax record, the usual procedure is to render the surface conducting by brushing into it an extremely fine conducting powder. It is then electroplated. The technique in this step varies somewhat among the various companies producing records, although fundamentally the process is the same with all. The electro-plate thus made, a negative of the original wax, is called a "master." From it two test pressings are usually made, using a molding compound such as shellac containing a finely ground filler. If they are satisfactory the master is then electro-plated after being treated to permit easy removal of the positive plate. From the positive, commonly called an "original," there is plated a second negative—a metal mold, commonly called a "stamper." From it, duplicate "originals" may be plated, and from them, duplicate "stampers." These successive plating processes involve no measurable injury to the quality of the record, and are comparatively simple and extremely safe in practice. By the custom of making a number of duplicates the master is protected from accidents to which it would be subject were it to be used directly for making finished records. The stampers instead are used to mold the final product, or "pressing"; it is not unusual to make a thousand pressings from a single stamper. Test pressings are commonly obtained from the wax in twelve hours, and recent refinements have so reduced the time for the various processes that finished pressings may now, when necessary, be obtained within three hours after

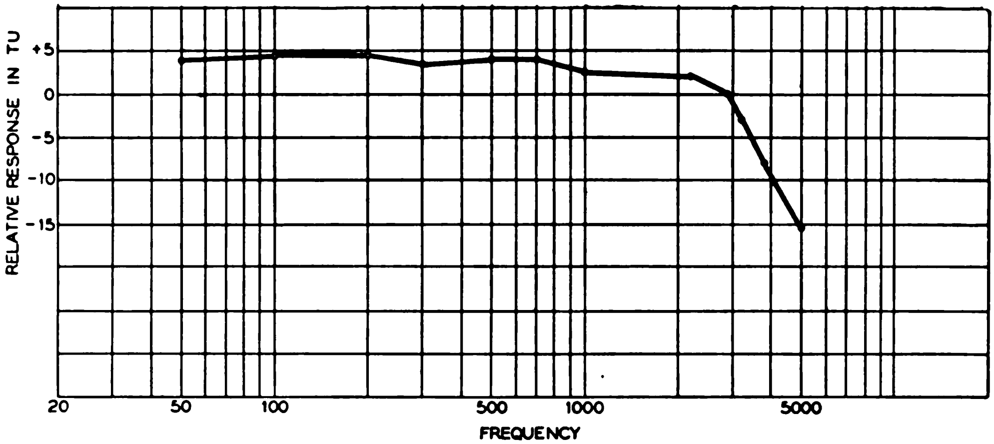


Fig. 7—Response of the wax playback of Fig. 6 *driven by a constant-velocity wax record.*

delivery of the wax. The pressing copies the wax record with such a high degree of accuracy that if frequency characteristics alone be considered, it shows almost complete perfection. Moreover it is cheap and durable, and as with an ordinary phonograph allows reproduction of sounds without careful adjustments or complex apparatus.

Various materials have been used in making the pressings. In some cases the material has been homogeneous, and in others the surface and the body of the record have been of different materials. Some records have been of laminated structure. There has not, however, been much latitude allowed the experimenter in his selection of materials. The records must be quite hard and, to have a reasonable life, must contain enough

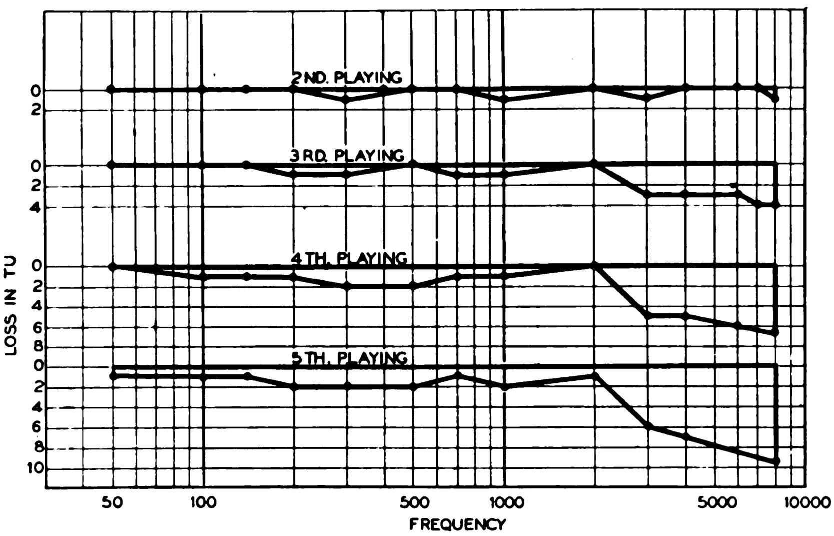


Fig. 8*—Loss in response of a wax playback driven by a constant-velocity wax record, on successive playings.*

abrasive to grind the needle quickly to a good fit. At the beginning of the run of a new needle the pressures are very high, on account of the small bearing surface. They decrease rapidly however, so that with an ordinary loud steel needle in a phonograph of the usual type the bearing surface is increased to such an extent after one minute's wear that the pressure is only about 50,000 pounds per square inch. The high pressures and the necessary abrasive characteristics have introduced irregularities which are responsible for most of the extraneous noise commonly known as "surface" or "needle scratch."

Recent development in the material of the finished records, together with refinement in the plating processes, have reduced the surface noise of records used in Western Electric Company theatre equipment by fifty to seventy-five per cent within the last two years. It is not necessary to reduce the level of surface noise to the zero-point, but merely to the threshold of audibility under the minimum auditorium noise. Moreover, the important point is not the absolute amplitude of the imperfections giving rise to surface noise but their relative magnitude with respect to that of the useful sound amplitudes. Thus an effective reduction in "surface" could be made by using larger records or reducing the playing time of the present records, in either case increasing the spacing of the grooves and the amplitude with which they are cut. Conversely, any large reduction in surface noise made by an improvement in the record material would make it possible to increase the playing time for records of a given size. There is no known absolute or fundamental reason why further improvements in record materials may not be expected, with corresponding reduction in surface noise. Furthermore large advances in pick-up design offer distinctly new possibilities for reduction in "surface."

It has sometimes been thought that in order to reproduce high frequencies properly, the linear speed of the record would have to be increased or the size of the needle point reduced. The factor determining whether a needle will follow the undulation of the groove is not its diameter relative to the length of the undulation, but the relation between the radii of curvature of the needle and the bend of the groove. At present the bearing portion of a representative needle

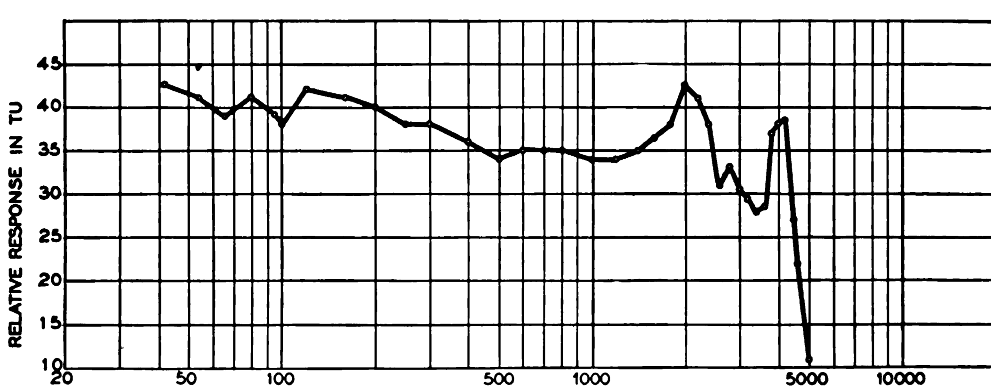


Fig. 9—Response of a 2-A pick-up driven by a constant-velocity pressing.

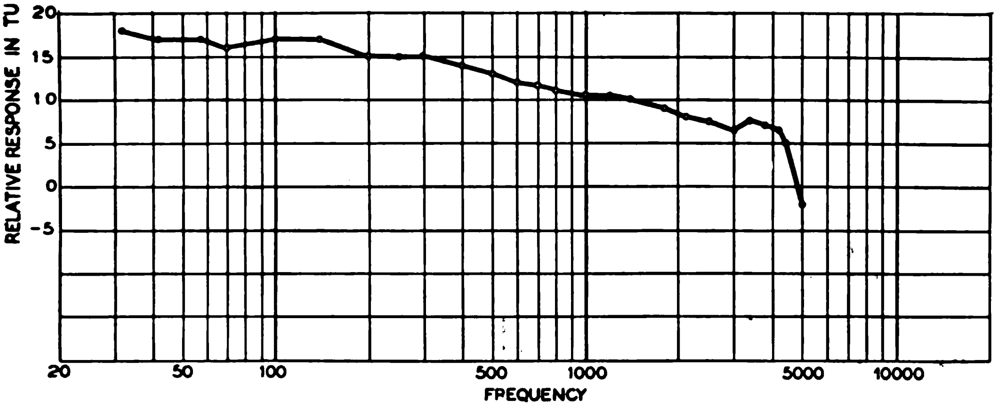


Fig. 10—*Response of a* 4-*A pick-up driven by a constant-velocity pressing.*

is about 0.003 inch in diameter whereas the half wave-length for a 5,000 cycle wave is 0.0014 inch. As mentioned before, the amplitude at 5,000 cycles would be only about 0.0001 inch if sounds of that frequency were as intense as those of lower frequencies. With the assumption of an amplitude of 0.0001 inch at 5,000 cycles and a linear record speed of seventy feet per minute, the minimum radius of curvature of the undulation is 0.00193 inch. On a corresponding basis, the radius of curvature of the undulation becomes equal to that of the needle point at about 7,000 cycles. As a matter of fact, sounds of 5,000 cycles or more in speech and music are characterized by lower intensity than those of lower frequency, and the amplitude of their undulations is correspondingly less. Present commercial needle points are therefore quite capable of following the undulations up to frequencies of at least 10,000 cycles. The limitations to high-frequency reproduction commonly found in the past have come from imperfections in the design of the pick-up or reproducer. They were caused mainly by inability of the record groove to drive the needle point, with resultant chatter, and by failure of the pick-up structure to transmit high-frequency motions from the needle point to the armature.

Large advances have been made within the last two or three years in designing electric reproducing structures. The mechanical impedance at the needle point has been reduced so that the point follows the undulations of the groove truthfully without the necessity of somewhat destructive bearing pressures. At the same time the mechanical transmitting structure has been so designed that a very broad range of frequencies is conveyed properly from the needle point to the armature. Moreover, proper mechanical loads have been provided so that the vibrations are absorbed after they operate the armature; resonance as ordinarily considered has been eliminated.

The curves shown in Figures 9 to 11 show the improvement which has been made. The pick-up shown in Figure 10 is free from the resonances shown in Figure 9. In the earlier pick-up there were high needle-point impedances in the region of these resonances, involving large driving forces destructive to both needle and record. Certain records were injured by only a few playings with this reproducer.

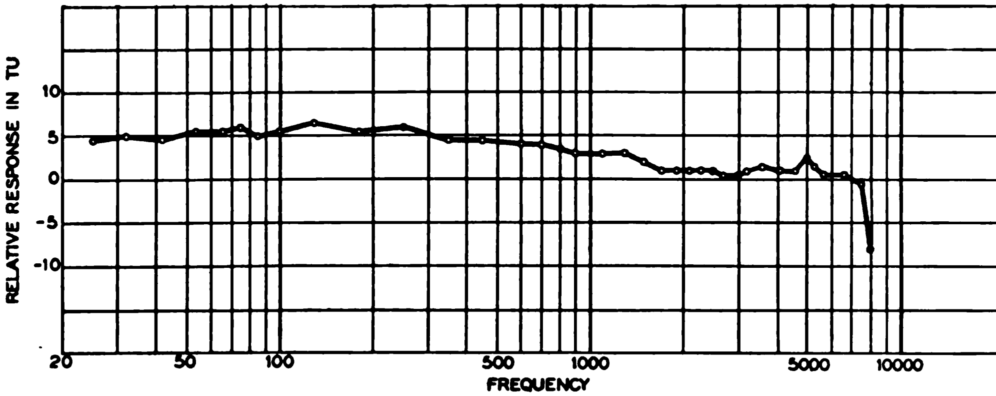


Fig. 11—*Response of experimental pick-up driven by a constant-velocity pressing.*

The reproducer of Figure 10 is characterized not only by considerably reduced average needle-point impedance but, as shown on the curve, by a practical elimination of resonance. Hence there is an even greater reduction from the maximum impedances which occurred at resonance in reproducers of the earlier type. Both needles and records have a longer life with the later type pick-up, which has been in commercial use for several months. In addition, as is seen, the higher frequencies are reproduced in considerably better fashion. A third curve, Figure 11, was obtained with a more recent experimental model in which a lighter, though very much more rigid, structure is used to connect the needle point with the armature. In this model a further large reduction in needle-point impedance has been effected, with corresponding reduction in wear on the records; in addition greatly improved reproduction has been secured at the high-frequency end of the scale.

The developments and inquiries heretofore discussed, although in many cases undertaken for their application to sound pictures, are of direct application to phonograph reproduction for any purpose, irrespective of whether the sound is to be accompanied by a film. Application of the processes to records which are to be synchronized with motion pictures has in addition involved meeting a number of conditions not previously encountered in the phonograph field. One of the most important of these relates to editing, cutting and rearranging of a picture, with the attendant necessity of rearranging the speech or music. Various methods have been used to copy or "dub" a disc record by playing it and recording on a new wax the parts that are wanted. The prime requirement is that the sacrifice in quality be kept at a minimum. To attain this end records have sometimes been copied at very low speed. This method appears unnecessarily laborious and slow and the results obtained are not altogether satisfactory in the light of possibilities presented by pick-ups and recorders of the characteristics shown above. Rearrangment of material on records is entirely practicable, and portions may be deleted, new portions added, or new sounds added to those already recorded; in fact any changes of this type may be made which can be made in the picture. Although the detailed technique of rearranging, or

"dubbing," is not highly developed at present, its advancement appears to offer no serious technical difficulty. Hence the refinement reached will probably depend on the rate at which improvement takes place, and the extent to which the method is used in the field of sound pictures.

Sound Recording with the Light Valve

By DONALD MacKENZIE
Apparatus Development Department

OF the several ways by which sound can be recorded on motion-picture film, one has seemed to engineers of Bell Telephone Laboratories to offer most immediate promise. This employs a light beam of constant intensity and varying width to produce a trace of varying density. Modulation of the light beam is effected by an electromechanical light valve actuated by speech currents which have been amplified to a suitable volume.

The light valve consists of a loop of duralumin tape suspended in a plane at right angles to a magnetic field. When the assembly of magnet and armature is complete, the two sides of the loop constitute a slit 0.002 by 0.256 inches, its sides lying in a plane at right angles to the lines of force and approximately centered in the air gap. The ends of the loop are connected to the output terminals of the recording amplifier. If the magnet is energized and the amplifier supplies an alternating current, the loop opens and closes in accordance with the current alternations.

When one side of the wave opens the valve to 0.004 inches and the other side closes it completely, full modulation of the aperture is accomplished. The natural frequency of the valve is set by adjusting the tension of the tape; for reasons which involve many considerations, the valve is tuned to seven thousand cycles per second. Under these circumstances about ten milliwatts are required for full modulation at a frequency remote from resonance; about one one-hundredth of this power at the resonant frequency. The impedance of the valve with protecting fuse is about twelve ohms.

If this appliance is interposed between a light source and a photographic film we have a camera shutter of unconventional design. Figure 2 shows a diagram of the optical system for studio recording. At the left is a light source, a ribbon-filament projection lamp, which is focussed on the plane of the valve. The light passed by the valve is then focussed with a two-to-one reduction on the photographic film at the right. A simple achromat is used to form the image of the filament at the valve plane, but a more complicated lens, designed to exacting specifications by Bausch and Lomb, is required for focussing the valve on the film. The undisturbed valve opening appears on the film as a line 0.001 by 0.128

inch, its length at right angles to the direction of film travel. The width of this line varies with the sound currents supplied to the valve, so that the film receives exposure to light of fixed intensity during the varying time required for a given point to traverse the varying aperture of the slit.

Recording in the studio is carried out on a film separate from that which receives the picture. This practice permits the use of two machines to make duplicate sound records, an insurance which is well worth its cost. The practice of separate negatives for sound and picture also permits the picture negative to be developed and printed according to well-established technique, and allows the necessary latitude in developing the sound record. The recording machine is driven by a motor synchronously with the camera. Lest there be any variation in the velocity of the film past the line of exposure, the sprocket which carries the film at that point is driven through a mechanical filter which holds the instantaneous velocity constant to one part in one hundred.

In the recording machine a photoelectric cell is mounted inside the left-hand sprocket which carries the film past the line of exposure. Fresh film transmits some four per cent of the light falling on it, and modulation of this light during the record is appreciated by the cell inside the sprocket. This cell is connected to a preliminary amplifier mounted below the exposure chamber, and with suitable further amplification the operator may hear from the loud speaker the record as it is actually being made on the film. Full modulation of the valve implies complete closing of the slit by one side of the wave of current; this modulation may not be exceeded or photographic overload will abound.

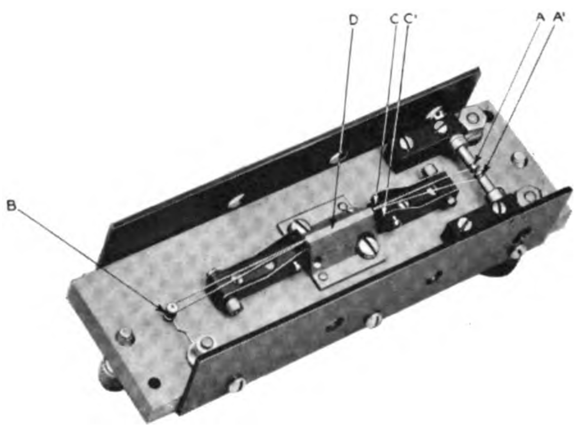


Fig. 1—*The light valve. A duralumin tape,* 0.006 *inch wide and* 0.003 *inch thick, is secured to windlasses A and A' and stretched tight by the spring-held pulley B. At points C and C' insulated pincers confine the central portions of the tape between windlasses and pulley to form a slit* 0.002 *inch wide. Supporting this loop and adjusting devices is a slab of metal with central elevation D, which constitutes the armature of an electromagnet. The central portions of the loop are supported on insulating bridges just above the face of D; here the sides of the loop are centered over a tapered slot. Viewed against the light, the valve appears as a slit* 2 *mils by* 256 *mils.*

Adding sound to the picture introduces no complication of studio technique other than to require sufficient rehearsing to make sure of satisfactory pick-up of the sound; microphone placement must be established and amplifiers adjusted to feed to the light valve currents which just drive to the edge of overload in the fortissimo passages of music or the loudest utterances of speakers. Provision is made for combining if desired the

contributions of several microphones on the set. This combination is under the control of the mixer operator in the monitoring room, who views the set through a double window in the studio wall. The mixer controls also the gain of the amplifiers for the recording machines. Relays permit the mixer to connect the horn circuit either directly to the recording amplifier or to one or the other of the monitoring photoelectric cells in the film recorders. The direct connection is used in preparing the sound pick-up in the studio: the program is rehearsed until satisfactory arrangement of microphones and of amplifier gain is effected. The electrical characteristic of this direct monitoring circuit is so designed that the sound quality heard in the horns shall be the same as the quality to be expected in the reproduction of the positive print in the theater. Acoustic treatment of the walls of the monitoring room secures the reverberation characteristic of the theater, and the monitoring level is so adjusted that the mixer operator hears the same loudness that he would wish to hear from the theater horns. It is capitally important that the operator judge his pick-up on the basis of sound closely identical in loudness and quality with that to be heard later in theater reproduction.

After the pick-up has been established on the direct monitoring circuit, the output of the recording amplifier is applied to the light valves and the monitoring horns are connected to the photoelectric cell amplifiers on the recording machines. With no film in the machine and at a convenient lamp current a complete rehearsal is made to verify the operation of the valves at the proper level. Film is then loaded, cameras and sound recorders are interlocked and starting marks made on all films by punches or light flashes.

A light signal from the recording room warns the studio, which after lighting up signals back its readiness to start. The machine operator starts the cameras and sound recorders, brings up the lamp current to the proper value, and when the machines are up to speed signals the studio to start. During the recording, the mixer operator monitors the record through the light valves, thereby assuring himself that no record is lost.

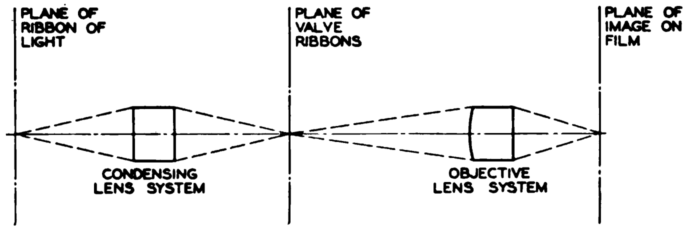


Fig. 2—Optical system for studio recording.

In printing these sound negatives in combination with pictures for projection in the theater, it is customary at the present time to print one negative, masking the space needed for the other, then to run the positive again through the printer with the other negative, masking the space already printed. In printing the sound negative, the light is regulated to result in thirty-five per cent transmission of the unmodulated track after positive development. Provision of suitable masks in the camera has been made to show in the finder and expose on the film only the portion

which will be available for picture projection. In the theater projector, the sound gate is located fourteen and one-half inches below the picture

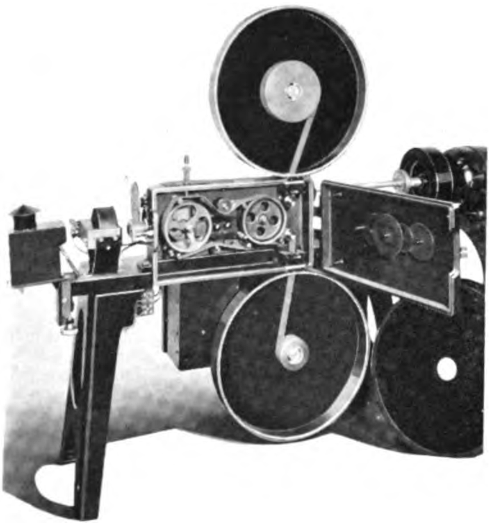


Fig. 3—A studio recording machine with the door of the exposure chamber open. The left-hand sprocket engages twenty perforations and is driven through a mechanical filter.

gate, in order to project the sound record at a point where the film is in continuous motion.

As with other systems for sound-transmission, that which includes film recording and reproduction has certain inherent faults which may be minimized by careful design. These are background noise, irregular response at various frequencies, and distortion due to non-linear characteristics.

Background noise results principally from casual variations in the light-transmission of both positive and negative films. Raw stock that is entirely satisfactory for pictures may be too irregular for sound records, since the photoelectric cell recognizes variations of 0.1 per cent while the eye ignores contrasts under two per cent. The remedy is to use "positive" stock for the sound negative as well as for the print and to use developer as little granular as possible in its effect. Fortunately, it is necessary to reduce the background noise only to a point below the threshold of audibility which will exist in the theater during the softer parts of the program. This point determines the level of the faintest sound-record which can be reproduced unmarred by noise.

Due to the facts that the element of illumination is 0.001 inch wide, instead of infinitely narrow, and that the film is travelling at ninety feet per minute, at a frequency of 18,000 cycles per second it will require the time of one cycle of a sound wave for a given point on the film to cross the slit. Then as each successive element of film crosses the slit, it will receive an exposure proportional to the integral of a complete cycle of the valve. Since the integral of one cycle is the same regardless of the phase at which the integral starts, each successive element will receive the same exposure, and the film will develop to a uniform density. Consequently no record will be made of the sound. Fortunately this frequency is far outside the range of interest to us, and the effect decreases as frequencies become lower. The drooping characteristic resulting, called the film transfer loss, may be largely offset by judicious choice of electrical characteristics and by tuning the light-valve mechanically to a frequency near 7000 cycles. How successful these measures are, in the range of importance in program reproduction, is evident from the curves of Figure 4.

When the curve connecting power input to the film system with its power output is not a straight line, dis-

tortion results, as in purely electrical systems. This takes the form of an introduction of harmonics of the frequencies normally present. The curve which connects exposure of photographic emulsions with resulting opacity is a straight line only when development is so controlled as to produce a contrast-ratio* of unity. Picture-recording practice is to develop the positive print to a contrast-ratio greater than unity. Development of the sound-negative is therefore so controlled as to give a contrast-ratio the reciprocal of that to be expected in the positive, so that the overall ratio is unity. Distortion from this cause is then so completely annulled that the resulting harmonics are undetectible.

The correction just outlined is available over only that part of the photographic range where exposure is correct. For exposures outside this range, the characteristic curve of film becomes curved in a way which cannot be compensated in the printing, and a liberal crop of harmonics is inevitable. However, the range of positive film is about twenty to one, and with the combination of light-source and optical system developed in Bell Telephone Laboratories, it is not difficult to set the unmodulated light at a value which will give an exposure of ten times that corresponding to the beginning of under-exposure. Then ninety per cent modulation of the light can be permitted without running into exposure on the "faint" side of the wave. For sound currents reaching one hundred per cent modulation of the light, ninety per cent of the wave is free from distortion; if the average light were halved, still eighty per cent would be free from distortion. There is therefore considerable latitude in the average exposure, and the negative is satisfactory if the transmission of the unmodulated track lies between fairly wide limits.

The volume of reproduced sound for a given reproducing light source varies directly with the average track density and the per cent modulation of this average. In printing the sound

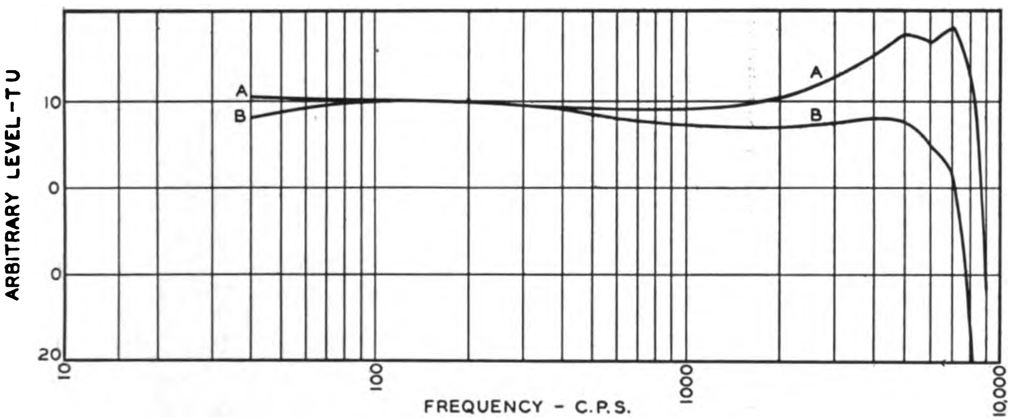


Fig. 4—Recording and reproduction characteristics: from acoustic pressure at microphone diaphragm to (A) light modulation by valve and to (B) current delivered to loud speaker in theater.

* *Technically known as "gamma," it is the slope of the Hurter and Driffield characteristic curve.*

negative, a uniform density for the print of the unmodulated track is desired, lest there be changes in the sound output during the showing. For Eastman positive film a suitable transmission of the unmodulated portion of the sound print is thirty-five per cent. At this average transmission only the peaks of the recorded sound will encroach on the region of under-exposure. For the reciprocally-developed negative track the region of under-exposure will have been reached by occasional peaks on the other side of the wave, and whatever photographic distortion exists will be balanced between positive and negative.

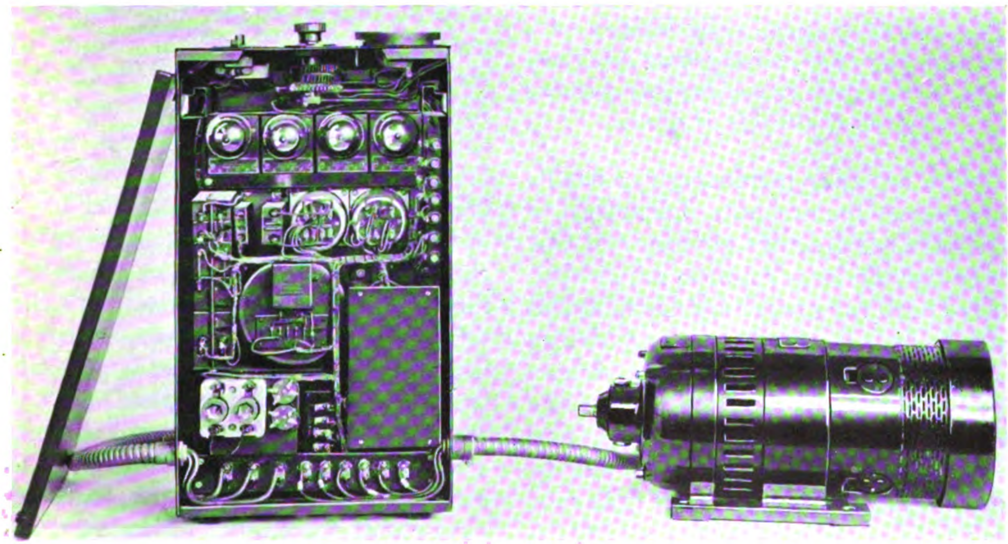
If the entire negative exposure has been confined to the under-exposure region of the emulsion chosen, a huskiness in the reproduction will result which can not be corrected by any known technique. But with correct exposure, which is readily possible with the light-valve method, ninety per cent of the wave will be clear of under-exposure, and experience shows that the ear detects no distortion. In telephonic terms, everything at a level one TU below full modulation will be free from distortion, and the peaks will be substantially perfect.

Speed Control for the Sound-Picture System

By HUGH M. STOLLER
Apparatus Development Department

SYNCHRONIZATION between sound record and film is required for all types of sound-pictures. In the Western Electric System it is secured by electrical methods for the recording apparatus and, for the reproducer, by mechanically coupling the picture projection machine and the sound record. With satisfactory synchronization thus secured, there still remains, however, the problem of speed control. Musical pitch varies directly with frequency or rate of vibration. The faster the record is rotated, the higher the pitch of the sound given out. In order, therefore, that the reproduced music may be of the same pitch as that recorded, the record must run at an assigned speed, and to keep the pitch from varying during the playing of the record, this speed must be prevented from changing. To attain these ends, the speed of the driving motor must be accurately controlled.

In determining how nearly constant this should be held, the criterion is the smallest pitch change that is noticeable, and it has been found that abrupt variations are more readily perceived than slow ones. A good musical ear will detect sudden changes in pitch produced by a change in speed of only one-half of one per cent. To make sure, therefore, that a discernible change in pitch never arises, speed regulation better than one-half of one per cent is required at all times. As further allowances seemed desirable to provide a suitable factor



An alternating-current drive motor for the sound picture connected to the governor.

of safety, a regulation of two-tenths of one per cent was agreed upon.

A survey showed that no commercial governing mechanism was available which would meet the requirements. The most suitable was probably the governor used with ordinary phonographs. This governor applies friction as the speed increases,

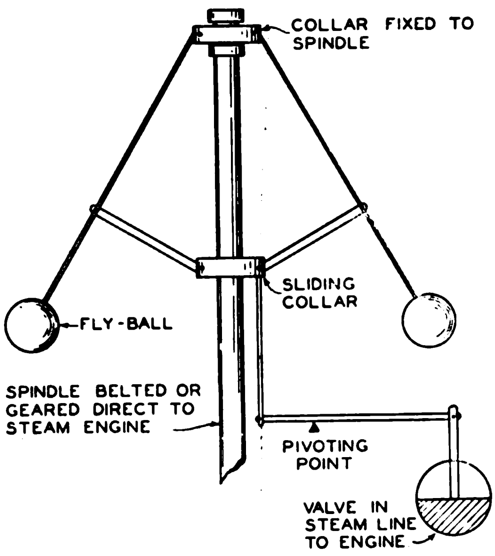


Fig. 1—Diagramatic representation of a fly-ball governor showing how sensitivity may be changed by moving the pivoting point to the left or right.

and it becomes increasingly difficult, because of maintenance difficulties, to design a satisfactory governor of this type for the larger motor required to drive both the projecting machine and turntable. A completely new design seemed the only satisfactory course.

The nature of the problem and the difficulties to be overcome are perhaps most readily brought out by considering a simple fly-ball governor controlling the speed of a steam engine, shown in Figure 1. Rotation tends to make the balls move outward due to centrifugal force. As they move out, however, they pull up a sliding collar and this action, through a system of levers, closes the steam valve supplying the engine, or in some other manner decreases the supply of steam, and the engine slows down. The tendency of the balls to fly outward is opposed by their weight so that there is a definite equilibrium position for each speed.

As a result of this the engine will run at a given speed for only one load. A load greater than this will require a wider valve opening so as to admit more steam, and this in turn will require a lower position of the fly-balls to allow it. This necessary drop in speed to allow a wider valve opening may be reduced, however, by moving the position of the pivoting point of the lever to the left. This changes the lever ratio so that smaller and smaller movements of the sliding collar will produce greater and greater valve openings. Inherently, however, some speed change must be permitted in order that the valve may be moved to accommodate the new load. To enable the engine to run at one speed regardless of the load requires an additional mechanism that will admit enough more steam to the engine to carry the increased load at the desired speed.

When, however, the sensitivity of the governor is made too great by moving the lever pivot too far to the left, or when the additional mechanism is added to make the engine always run at the same speed, an unstable condition is brought about. Under these conditions, the engine, at each action of the governor, tends to over-shoot its mark, either not attaining equilibrium speed at all or reaching it only after several oscil-

lations. This instability may be overcome by adding a dashpot or some similar contrivance to the governor which, allowing an initial rapid adjustment, will later introduce a slower compensating force that prevents oscillations of speed.

The same governing principles apply whatever may be the type of governing apparatus. A change in speed must be able to cause some force to act on the prime mover tending to counteract this change and, if the governing is to be made very close, some dashpot equivalent must be provided to prevent the tendency to hunt or oscillate back and forth before the equilibrium speed is reached.

The prime mover for the sound-picture equipment is an electric motor. Either direct or alternating current may be used but as the principles involved are the same with each, only the latter need be discussed. The speed of the motor used is controlled by changing the impedance in its armature circuit. With high line voltage or light load the impedance is made a maximum, while with low line voltage or heavy load the impedance is made a minimum. A suitable governor, therefore, must be arranged to change this armature impedance at a very small change in motor speed (below 0.2 of one per cent) and must incorporate some arrangement to prevent oscillations.

In the sound-picture system the somewhat cumbersome fly-balls with their sliding collar and connecting levers to the steam valve are replaced by a few comparatively simple electrical circuits which act silently and instantly to correct the slightest change in speed of the driving motor. The electrical governing apparatus may be split up into three parts corresponding to those of the fly-ball governor. One part will substitute for the driving link (not shown in Figure 1) between the engine and the governor spindle, another for the fly-balls themselves and their connecting levers, and a third for the steam valve that changes the torque of the engine.

The driving link for the electrical system is a 720 cycle generator coupled to the main driving motor of the projector unit.

The governing circuit proper is a special bridge circuit shown as Figure 2. One arm of the bridge has a fixed inductance and condenser in series, which are adjusted to tune the circuit to 720 cycles. At this frequency the impedance of this arm is a resistance only and the impedance of the arm D is made a resistance of the same value. At 720 cycles the ratio of these two arms, therefore, is unity, as is that of the other two arms, made up of the primary of a transformer divided at its half tap. The small

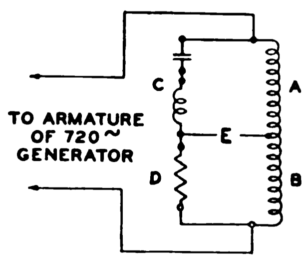


Fig. 2—The heart of the sound-picture governor. Potential E shifts 180° in phase as the speed changes from any value below 1200 r. p. m. to any value above it.

alternator, connected across the transformer, thus becomes the source of power for the bridge.

This arrangement makes an extremely sensitive analogy to the fly-ball governor and lever system. The potential, E, from the mid-point of

the coils A and B to the junction of arms C and D, which is zero at 720 cycles, shifts its phase 180° as the speed changes from any frequency below 720 cycles to any above it. Below 720 cycles the current in C is leading due to the predominance of the condenser and above 720 it is lagging due to the predominance of the inductance. Instead, therefore, of a gradual change as the speed changes from its desired value there is an abrupt one which furnishes a basis for accurate speed control.

Acting as the steam valve to control the speed of the motor is an impedance coil with three legs shown as Figure 3. The two outer legs, L_1 and L_2, are connected to the motor armature and serve as the impedance controlling the speed. The middle leg, G, carries a direct current winding. As the current in this winding increases the magnetic flux in the two outer branches increases to saturation and their impedance decreases. The torque of the motor varies inversely with the reactance of the coils, L_1 and L_2, and as a result the greater the direct current flowing into the coil G, the higher will be the torque of the motor.

The link between the bridge and the three-legged inductance is a vacuum-tube circuit which causes more direct current to flow as the motor speed tends to fall. This complete circuit, shown in Figure 4, includes the detector tube V_4, and two tubes V_1 and V_2 which supply current for the middle winding of the impedance coil. Tube V_3 is a rectifier to supply excitation for the 720 cycle alternator and grid biasing voltage for V_1, V_2, and V_4.

Plate potential for V_4 comes from the alternator through the transformer T_4, and its phase is fixed. Grid potential for this tube is from the bridge output circuit, E, the phase of which shifts 180° as the alternator speed changes from below to above 1200 r.p.m. This 180° shift of phase changes the potential of the grid relative to the plate from negative to positive or vice versa, and thereby causes a relatively large change in the plate current, which, flowing through R_1 causes a correspondingly large change in the grid potential of tubes V_1 and V_2, and thus in the direct current to the impedance coil.

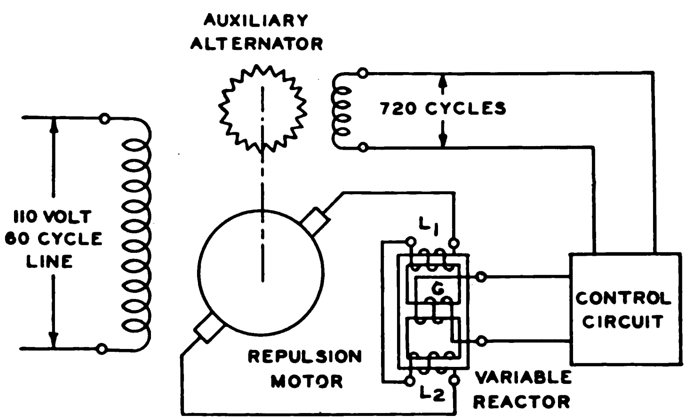


Fig. 3—Torque control for the driving motor is obtained by a three-legged inductance coil, the impedance of which is changed by direct current flowing around the middle leg.

The bridge circuit makes a very sensitive governing device but with it alone some permanent change in speed would be required to compensate for each change in load or line voltage. Something else must be added if the speed is to be constant

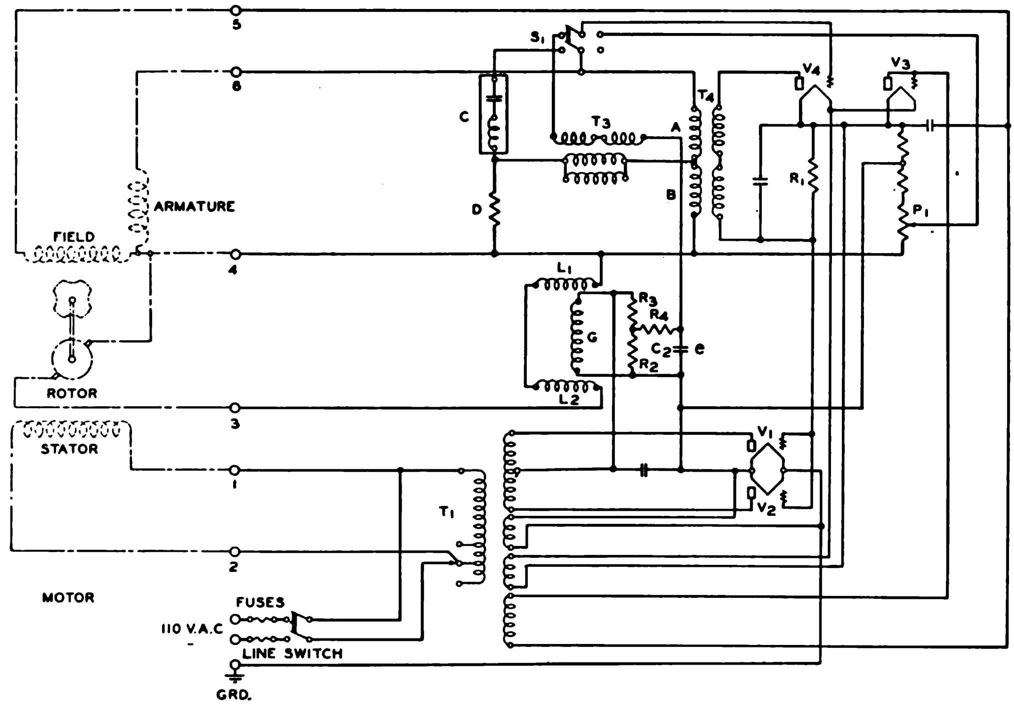


Fig. 4—Complete diagram of the governing circuit showing the three-legged reactance coil in the center. Switch S_1 is normally thrown to the left.

for all conditions. Also, some dash-pot equivalent must be used to prevent the speed oscillations mentioned.

These two functions are accomplished by a network composed of R_2, R_3, R_4, and C_2, properly connected to the other circuits. Current flowing in the plate circuit of V_1 and V_2 to the coil of G flows also through R_2 and R_3. The drop across C_2 which after a short preliminary period is the same as that through R_2, feeds back a potential to the grid circuit of V_4, and thereby causes the additional regulation required. To slow down the action of this feed back, however, R_4 in series with C_2 is connected in parallel with R_2 as shown. The feed back potential is that across C_2 and this rises or falls slowly as the condenser must be charged or discharged through the high resistance R_4.

By these means, in the comparatively simple and compact electrical circuit shown in the accompanying cut, is provided a governor, similar in its functioning to the fly-ball governor of Figure 1, that will control the speed of the driving motor under all ordinary conditions to within the required two-tenths per cent. The switch S_1 was added to the circuit so that, when the picture-projection machine was used for ordinary silent motion-pictures, when such close speed regulation is not required, it could be thrown to the right and hand regulation obtained by the potentiometer P_1. This is needed to vary operating speed of the projector to meet a definite time schedule for showing the picture. When the schedule permits, however, accurate speed regulation is preferred since it enables a leader to keep his orchestra in better step with the picture.

Sound Projector Systems for Motion-Picture Theaters

By EDWARD O. SCRIVEN
Apparatus Development Department

IN theaters at which motion pictures accompanied by synchronized speech or music are presented, the records come in two forms. Some are composition discs similar to ordinary phonograph records, while others are standard motion-picture film bearing at one side a track of alternate light and dark bands, of varying density. In either case there must be apparatus synchronized with each projector to derive from the records an electric current in which all the variations in pitch and loudness are accurately represented. There must in addition be apparatus to amplify the current, to effect its conversion into sound and so to direct the sound into the theater auditorium as to create the illusion that it emanates from, rather than merely accompanies, the picture. When a theater is being prepared for presenting sound pictures, the film projectors in use are ordinarily retained but each is fitted with a new motor and driving mechanism; it is provided with a turntable and electric pick-up for disc records, and with analogous equipment for film records, or both. The pick-up used for disc records is in some ways similar to the reproducer of an ordinary acoustic phonograph, with a needle holder connected to a clamped diaphragm of highly tempered spring steel. To the diaphragm there is fastened an armature made of a special high-permeability alloy, so arranged that as the diaphragm and the armature vibrate, the flux in the air-gap of a permanent magnet varies correspondingly; in appropriately placed coils currents are induced which are the electric representation of the wave groove which moves past the needle. Although this instrument delivers energy at a comparatively low level, it has a very uniform response over a wide range of frequencies. That result has been secured largely by preventing distortion which would arise from resonance in any part of the system; the members have been designed with natural periods

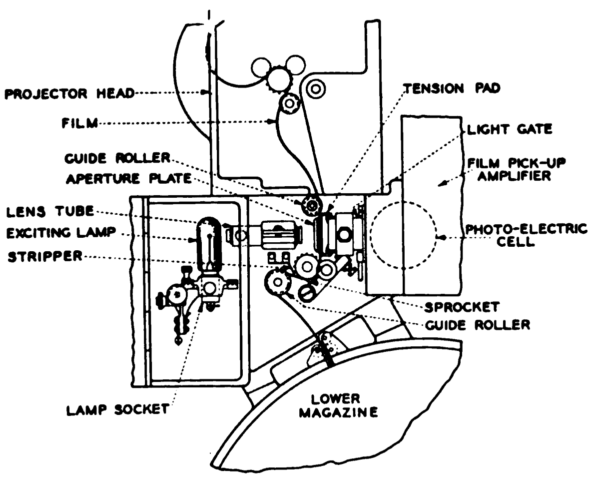


Fig. 1—Arrangement of projector for reproducing from sound films.

beyond the range of frequencies to be transmitted, and the magnet chamber back of the diaphragm is filled with a heavy oil to damp free vibration.



Fig. 2—Photoelectric cell of the type used for reproducing from sound film.

tion. The films used with the disc records, called synchronized films, differ from ordinary films only in that one frame at the beginning of each is marked to give the starting point.

With the optical or film records, the sounds are represented by parallel bands, alternately light and dark. Intensity or loudness is represented by differences in density of the record, and pitch by the closeness of the bands. For reproduction from these another apparatus group is required, and it too is connected to the projector. A narrow light beam of high intensity passes through the film record and falls upon a photoelectric cell to produce a current corresponding to that from the original recording transmitter. There is fastened to the projector an "exciting" lamp and a system of lenses for focusing its light upon an aperture 0.0015 inch by 3/16 inch; by other lenses the image of the aperture is then brought to focus upon the film record as a line 0.001 inch by 0.080 inch. Since the track on the film is 0.100 inch wide, there is an allowance of 0.010 inch on each side for variation in its position. The position and focus of the lens tube are fixed, but the exciting lamp is mounted on a movable carriage so that new lamps as installed may be brought properly into focus.

A photoelectric cell of the type used is shown in Figure 2, and the circuit in Figure 3. When polarized by a proper voltage, the cell passes a current proportional, within limiting values, to the intensity of the light falling upon it. The polarizing voltage is supplied to the cell through such a high resistance that in operation there is obtained from the cell a voltage across the resistance proportional to the incident light. The

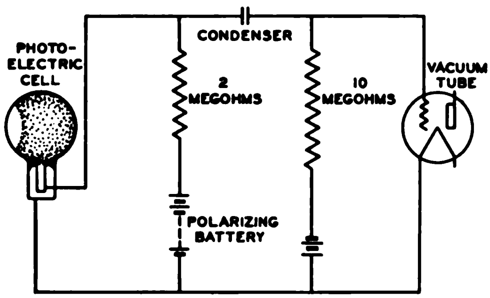


Fig. 3—Circuit from the photoelectric cell to the adjacent amplifier.

voltage bears therefore at any time an inverse relation to the density of that part of the sound track then between the exciting lamp and the cell.

The photoelectric cell circuit is inherently one of high impedance. In such a circuit local interference—"static," to use the radio expression—is readily picked up, and since the

energy level is low, the current so acquired may be appreciable in comparison with the sound currents themselves. In addition the shunting effect of the capacity between the conductors

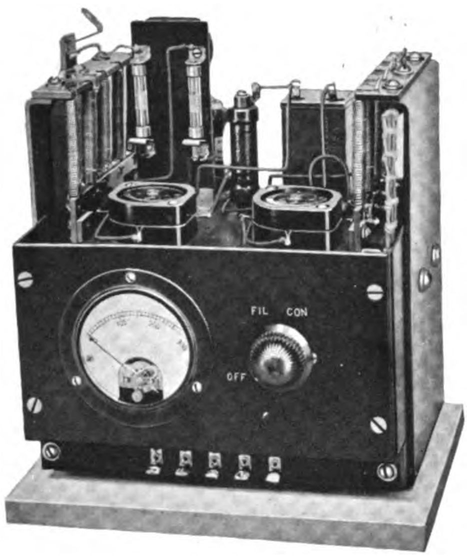


Fig. 4—Amplifier to which the photoelectric cell is connected, showing the suspension for absorbing vibrations. The tubes are not in place.

is noticeable, particularly at the higher frequencies. Hence a vacuum tube amplifier, which serves both to increase the energy and to make that energy available across a low impedance circuit, is closely associated with the cell upon the projector itself. Cell and amplifier are enclosed in a heavy metal box made fast to the frame of the projector, and the frame is carefully grounded. As a further precaution, the amplifier is supported within the enclosing box by a rather elaborate flexible suspension, lest vibration of the vacuum tubes introduce noise components into the current. The amplifier brings up the energy level to about that obtained from the magnet coils of the reproducer for disc records.

It is evident from the relative location of apparatus, shown in Figure 1, that it is not feasible to print the film with the pictures directly opposite corresponding parts of the sound record. Furthermore the pictures move intermittently before the projection lens, while the sound record must of course move uniformly in front of the photoelectric cell. Picture and sound record are therefore separated longitudinally by 14½ inches, and a certain amount of slack is allowed between the sprocket carrying the film in front of the projection lens and that carrying it before the photoelectric cell. To prevent vibration of the projector or variations in the supply voltage or load from varying the speed of the latter sprocket, it is connected to the other moving parts of the system by a mechanical filter which absorbs any abrupt changes in speed. The driving motor is held electrically at the correct speed, but at will the automatic control can be disconnected and the speed regulated manually by the operator.

As with ordinary motion-pictures, two projectors must be used alternately to present a continuous program. At the end of a record, the music or speech coming from one machine must be blended imperceptibly into that from the other just as the picture from one reel is faded into that from the next. At the end of each sound film or disc the music overlaps that at the beginning of the next; to make the transition there is a device called a fader, a double potentiometer. As the starting projector goes into operation, the fader knob is turned and the current delivered to the amplifiers is changed quickly until it comes entirely from the

new record. Ordinarily the fader is installed with auxiliary dials and handles, so that the operator can control it from any position around the projectors. In its lower range, used in changing between projectors, the steps are rather large, whereas in the upper range the volume changes in scarcely perceptible steps. The fader thereby fills another use; it makes possible any volume of sound desired, within reasonable limits, by choice of the proper step in the upper range, and thereby permits equalizing the level of sound obtained from different records. There is provided as well a switch for changing from film to disc records, and the reverse, and a key for connecting a spare projector in place of either of the regular machines.

After passing through the fader, the sound currents go to the main amplifier, where their energy is raised to a level adequate for the loud speakers of the particular theater. This combination of apparatus is capable of multiplying the energy 100,000,000 times, and is so designed that all frequencies in the range from 40 to 10,000 cycles are amplified about equally. A potentiometer is provided on the amplifier but after it has once been adjusted at the time of installation it is ordinarily not changed; necessary adjustments in energy level are made on the fader instead. The amplifier* is built in three units, of which the first consists of three low-power tubes connected in tandem, resistance coupled, with the filaments heated by a twelve-volt battery. In the second unit there are two medium-power tubes with a push-pull connection, whose filaments are heated by low-voltage alternating current. Two similar tubes in this unit act as a full wave rectifier, and supply rectified alternating current for the plate circuits of the amplifier tubes in the first

* *Described by H. A. Dahl in the* Record *for May,* 1928.

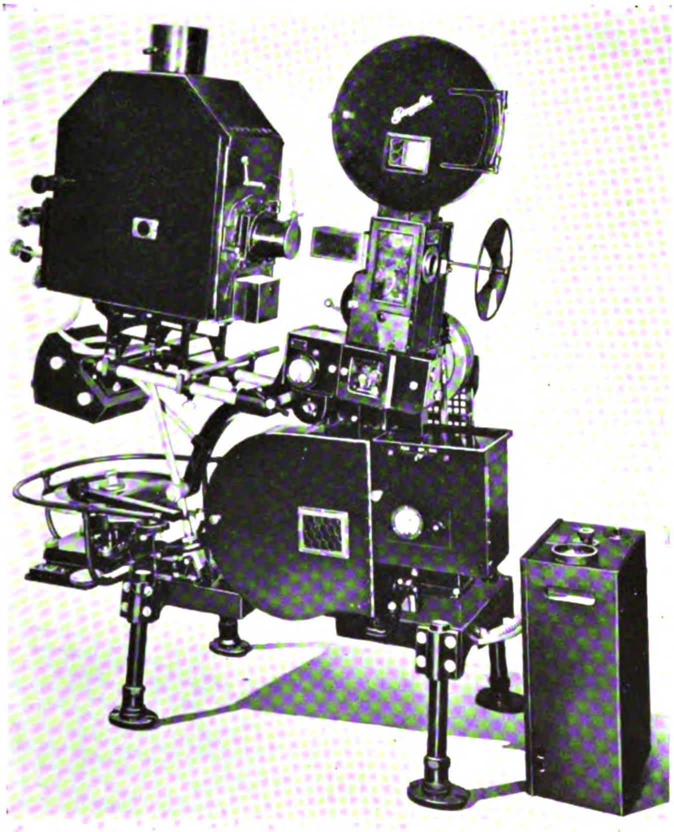


Fig. 5—Western Electric projector for sound pictures, using a Simplex head. A Powers or Motiograph head may also be used.

and second units. The third unit has a single stage of high-power push-pull amplifier tubes and push-pull rectifier tubes; like the second, it operates entirely on alternating current. The three units can be arranged to meet any conditions. In small theaters only the first two are required, and in larger houses the high-power unit, the third, is used as well. For unusual conditions two or more of the high-power units may be operated in parallel from the output of the second unit to give a greater volume of sound.

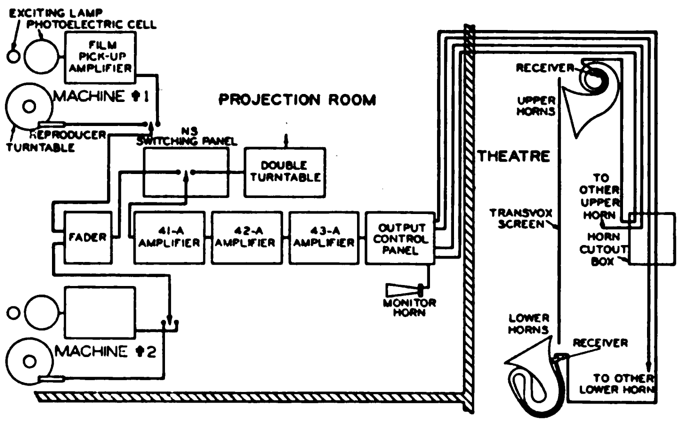


Fig. 6—Layout of a typical theater for presenting sound pictures.

Following the amplifier there is an output control panel consisting of an autotransformer having a large number of taps which are multipled to a number of dial switches. To the switches are connected the loud-speaking receivers, so that the impedance of the amplifier output can be matched to the desired number of horns. Thereby there is secured the most efficient use of the power available, and adjustment of the relative volumes of the individual horns is made possible at any time.

A theater installation ordinarily contains four horns. They are mounted behind a transvocent screen, on which the pictures are shown, so that the sound may seem to come directly from the picture. Two horns are mounted at the line of the stage and pointed upward toward the balconies and two are mounted at the upper edge of the screen, or above it, and directed downward.

One or more Western Electric No. 555 receivers* are used with each of the horns. Since these show extremely high efficiency, converting into sound energy thirty per cent of the electrical energy supplied them, they reduce to a minimum the output required from the amplifier. A horn is ordinarily fitted with one receiver, but for outdoor use or other special requirements it may be fitted with two, four or nine by a throat such as that shown in Figure 8. The maximum electrical input to a horn for continuous safe operation is ap-

* *Described by A. L. Thuras in the* RECORD *for March, 1928.*

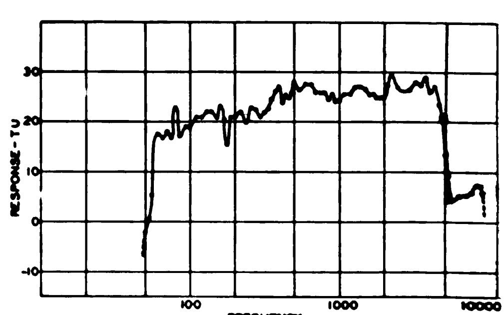


Fig. 7—Response-frequency characteristic of exponential horn and 555-W receiver.

proximately five watts per receiver. To disperse the sound-waves over a large angle, more horns are needed than for a comparatively small angle. This directive characteristic of the horns is important, since it is responsible for the illusion that the sound comes directly from the mouth of the horn, that is, from the screen. When the horn is replaced by a loud speaker of otherwise identical characteristics which radiates its sound over a very wide angle, the sound seems to come from a point some distance behind the screen, so that the illusion of coming from the picture is destroyed.



Fig. 8—Throat by which a horn may be fitted with nine receivers, for outdoor use.

In addition to its function as a part of the talking motion-picture equipment the sound projector system may also be used as a public address system for voice reenforcement.

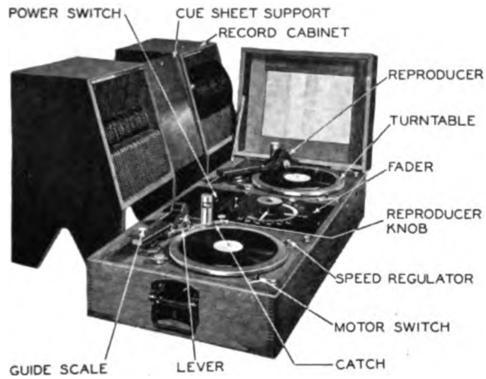


Fig. 9—Cabinet for reproducing from disc records not synchronized with pictures.

Microphones may be concealed in the footlights, and the horns so placed as not to affect them; for announcements ordinarily there will be a transmitter in the manager's office.

By means of auxiliary equipment provided, the system can also be used to provide non-synchronized music as an accompaniment to pictures. There is a cabinet containing two turntables, each with a pick-up and means for locating it accurately upon a record, and a fader to make possible continuous playing. The same amplifier and loud speakers are used as for the synchronized speech and music.

Installation and Adjustment of Western Electric Sound-Projector Systems

By HOWARD B. SANTEE
Electrical Research Products, Incorporatea

THAT there may be realized the full advantages which a Western Electric Sound-Projector System can bring to a theater, each installation is planned and directed individually by engineers of Electrical Research Products, Incorporated, the organization which provides the apparatus. Preceding the installation, engineers of that company conduct a detailed preliminary investigation to decide upon the exact apparatus, and to determine any changes that may be needed in the theater building. The equipment is installed under supervision of an engineer of the organization who in addition sees that whatever supplementary work was needed in the building has been carried out properly. As the work proceeds he sees that the equipment is so placed and so regulated as to give the best results, and as the various pieces of apparatus are made ready for use, he trains the projection-room employees in their operation. Finally the completed installation is kept at the highest standard of operation and maintenance through supervisory visits made at intervals by a field engineer, and routine maintenance work is directed by the organization's service group.

Although its need may not at first be fully apparent, the preliminary survey receives the most careful attention to insure that everything will be in readiness for the work of installation to progress smoothly, and that the apparatus best suited for the particular theater will be used. Acoustic characteristics of the stage and auditorium receive thorough study, upon which in many cases the success of the installation rests. Size and location of the stage are noted, for their bearing on placing of the horns and of the special screen needed. Where blue-prints of the theater building are not available, the engineer must measure the dimensions himself and must prepare sketches showing the size and shape of the auditorium and the number and arrangement of the seats. He must also appraise the acoustic characteristics, discovering any sections where there is an echo, interference, noise from an extraneous source, or any other hindrance to proper hearing. A final study of acoustic conditions is best made on completion of the installation, but data obtained during the preliminary survey give a useful basis for the installation work.

In the projection room the engineer notes the type and condition of the projection machines, the power supply and its regulation, the angle of projection. He sees whether there is room between the machines to allow convenient operation after installation of the sound apparatus, and whether there is a suitable space for

the amplifier and the associated controls. In cases where the room is inadequate he decides upon the rearrangement or enlargement that is needed.

At the end of the study, the engineer's recommendations, along with the sketches and detailed information on which they are based, are submitted to the home office. There all the circumstances are examined again, and a report embodying a final set of recommendations is prepared.

When details of the installation are fully determined, dates are assigned for shipping the apparatus and for the start of the installers' work, and the theater management is informed. The management is in addition notified at this time if architectural changes are needed in the projection booth or elsewhere, so that they can be finished before the work of installation is commenced.

The entire work of installation is directed by a field engineer whose main function is to see that all parts of the work, and all supplementary work in preparing the theater, are so carried out that the completed system will operate at its full possibilities. He first establishes satisfactory contacts with the theater manager and staff, and with information obtained from them coordinates the work of installation, testing and rehearsal with circumstances necessary for operation of the theater during the preliminary period. Likewise he chooses an electrical contractor, if possible one already familiar with the wiring in the theater. Thus he insures that the work will proceed smoothly, and that everything will be ready for the scheduled opening.

Most commonly the work starts at the projectors themselves. While these remain practically intact in other respects, on each the driving motor is replaced with one whose speed is regulated electrically. As these motors require from four to five seconds to come up to running speed, it is desirable to have them in place early, that the projectionists may become accustomed to them and so be able to give full attention to handling the records by the time sound programs are to be presented. Next the batteries are installed, with their switching panel and charging apparatus, and a motor-generator if that is to be used. The rack for the main amplifier is placed in position, and the units mounted upon it. Next the fader is installed, and its auxiliary controls put in place and connected to it. Likewise the monitoring horn is mounted at a carefully chosen location in the operating booth, so that the projectionist will be able to hear the program clearly at all times and thus be prepared for the fader changes between records. Usually the turntable and pick-up for disc records are then installed on each machine and, for film records, the exciting lamp, lenses, photoelectric cell and associated amplifier, and subordinate equipment; in some cases however these members are assembled on the projectors before the main amplifier and fader are installed. Although the reproducing apparatus adds materially to the mechanism of a projector, the parts have been so designed for each of the commonly-used makes of machines that their installation does not involve loss or extensive change of parts not immediately involved. Since the conduit and wiring work have been keeping pace with the installation of equipment, it should now be possible

to connect the pieces of apparatus and check their correct installation and the wiring work.

Installation procedure is constantly being improved, and within a few months a noteworthy advance is to be made. In the present arrangement the driving motor and disc turntable are mounted on individual pedestals, the film reproducer and associated amplifier are supplied as separate units to be mounted on the projector, and the film-discs transfer panel is mounted on the wall of the room. Instead there will be a single pedestal bearing all of these members. The change will facilitate the work of installation and reduce the wiring needed, and furthermore will make the work of operation more convenient as well.

With the work well advanced in the projection room, the engineer next turns his attention to the stage. The horns are placed on their mountings, which should be ready by this time, at locations presumably correct for the size and shape of the auditorium. After the loud-speaking receivers are attached and connected, there is the first opportunity to produce sound through the complete system. A cursory test follows to assure that no major errors are present, and any immediately obvious imperfections are corrected. Comparative tests are then made between the reproducers on the projectors, so that any discrepancies in volume can be overcome. Each receiver and horn is heard separately, and then they are operated in unison so that the engineer can check their proper poling. Before the work proceeds further, the semi-porous screen on which the pictures are to be shown is installed immediately in front of the horns. Through this the sound will pass, seeming to come from the pictures themselves.

Although for hearing of speech reverberation is objectionable as preventing good articulation, when not excessive it is desirable for music since it tends to give the effect of fullness and roundness.* A varying factor complicating the situation further is the absorbent property of the audience itself. There are theaters which empty, are entirely too reverberant, but which are thoroughly satisfactory when filled. Attendance varies at different performances of course, so that at best a compromise must be tolerated in considering acoustic adjustments.

While the use of ordinary drapes and similar material causes absorption of the higher frequencies to a somewhat greater degree than the lower, it is about the only practical method which can be employed to overcome acoustic difficulties from excessive reverberation and echo. Excessive damping must be avoided, to prevent a deadness in the sounds which may almost be depressing. Heavily damped houses require greater amplification than would otherwise be necessary but the presence of the audience has less effect than in a somewhat more reverberant house.

Correction of specific acoustic faults may be made with almost complete success, however. Echoes may sometimes be corrected by moving one or more of the horns, but the reflecting surface must be covered with heavy drapes when it is so located that no suitable echo-free position

* *For a consideration of auditorium acoustics see Speech Interpretation in Auditoriums by E. C. Wente,* Bell Laboratories Record, *October,* 1928.

is available for the horns. Interference usually results from reflection of sounds, and likewise can be prevented by adequate covering of the surfaces responsible. Resonance occurs when a surface made up of a thin, hard material, free to act as a diaphragm at its own natural frequency, is in the path of the sound waves. Distortion necessarily results, since only that part of the sound near the natural period of the resonator is reenforced. Here again covering is ordinarily the treatment used.

Bearing in mind the three prime requisites to good hearing, that sound be sufficiently loud for all auditors without being unnaturally loud for any, that successive sounds be clear and distinct, and that the components of complex sounds retain their relative intensities, the engineer makes the acoustic adjustments. He usually tests first for sound distribution, arranging the horns so that as far as possible all parts of the house receive the same volume. Proper flaring and tilting of the horns is usually sufficient to give adequate distribution. Any acoustic peculiarities are next investigated, and where possible corrected. Many hours are often spent in moving the horns and adjusting their placing, since slight changes in position sometimes produce marked differences in the acoustic effect. When the best results demand further acoustic treatment of the auditorium, involving alterations to the building or extensive change of the wall surfaces, the manager is so informed.

One standard practice followed in all cases is to cover the horns, and the back of the screen except the areas occupied with the horns, by absorbent drapes. It is usual also, where the screen is set back from the proscenium arch, to hang drapes around it, in shadow box effect. By these precautions back-stage echoes and reflections are avoided.

After the horn locations have been definitely fixed and the equipment given a final check, the engineer calibrates the amplifying apparatus for the particular theater. He has at hand several test records which make available a wide variety of the types of entertainment to be shown, each marked with the fader setting determined in a theater which has been chosen as "standard." By playing these records with the fader set at the marked value and adjusting the main potentiometer until the proper effects are obtained, he sets the potentiometer at a presumably permanent adjustment, in keeping with the size of the theater, so that in the future good results can be obtained from any records by adjustment of the fader only. In addition, various types of records require that varying volumes be obtained from the different horns. From the tests the engineer can choose the relative volumes for different types of selections, and establish the horn settings which will normally be required.

During progress of the installation, the projectionists and their assistants are instructed in the operation and maintenance of the new equipment. At the outset each man is given a complete operating instruction bulletin, which gives detailed information on every necessary point. By the time the theater is calibrated the men should be familiar with their new duties, and should be able to present a complete program without assistance. An opportunity soon comes to show their facility, in the rehearsal of the opening program.

At the early performances the closest attention is given, to be sure that the system is being operated to give the desired effects. In addition, however, watchful attention should be continued as a permanent function of the theater management, if the best results are to be secured. Whenever a sound program is in progress either the manager or somebody specially appointed should be present in the audience. By his own reactions, and by noting the effect on the audience, he observes the need for any changes in volume or otherwise. Likewise he watches for any extensive change in the degree to which the house is filled, or any other circumstance having a bearing on the picture as presented. A buzzer signal and a telephone are provided for communicating instructions to the operating room.

The installation engineer remains at the theater until it is evident that the local staff are fully competent to continue independently. At that time the installation is transferred to the service organization of Electrical Research Products, Inc. The service engineer in whose district the theater is located is available for emergency calls at all times. In addition, he makes scheduled visits to check the equipment and recommend any minor adjustments which may seem advisable. In this way each installation is given constant engineering supervision, to keep the sound equipment operating at the peak of performance which is possible.

Inspection Engineering in the Field

By A. G. DALTON
Inspection Engineering Department

DURING the week of October 1st to October 6th, there was held at the Laboratories a conference attended by all field engineers, by members of the American Telephone and Telegraph Company, the Northern Electric Company and the Western Electric Company, and by executives and members of the technical staff of the Laboratories. Members of the Inspection Engineering Department read several papers dealing with new quality standards and with progress in the art of determining the quality conditions of equipment in process of manufacture and in service. Recent developments in related matters of interest were discussed by other members of the Laboratories' technical staff. Social features of the conference served to bring the field engineers in closer personal contact with members of the Bell System with whom their relations in the past have involved only business matters.

The field engineering force was organized by the Inspection Engineering Department four or five years ago. Its members are recruited largely from the development departments, and are normally assigned to a particular group of telephone company operating areas for one or two years, making their headquarters with the Engineering Department of an Operating Company or with one of the Western Electric Company's departments in a city in the area.

The main function of this force is to keep the Inspection Engineering Department in touch with the performance of equipment developed by the Laboratories and with special conditions relating to its operation, maintenance or quality. The field engineer also acts as a general agent of the Inspection Engineering Department, and assists Operating Companies in preparing complaints and obtaining technical information or aid from the Laboratories. Through regularly scheduled review conferences with the Engineering Departments of the Operating Companies and the Installation Department and Distributing Houses of the Western Electric Company, the field engineer maintains the active contacts vital to his intermediary work. Suggestions from these organizations relating to the design or quality of systems, apparatus or supplies pass through the field engineer to New York for consideration, and his personal observation of the performance of communication equipment assists the Laboratories in studying the adequacy of current quality standards.

At the present time, there are ten field engineers assigned to telephone company operating areas, for the performance of this work throughout the country. The group is headed by R. J. Nossaman, a graduate of the University of Colorado, class of 1922, with field experience in New York, St. Louis and San Francisco.



Bell Telephone Laboratories' field engineers: back row: G. Garbacz, W. E. Whitworth, J. A. St. Clair, W. K. St. Clair, I. W. Whiteside, R. C. Kamphausen; seated: D. S. Bender, H. W. Nylund, T. L. Oliver, A. G. Dalton, G. D. Edwards, R. J. Nossaman, A. M. Elliott, H. J. Knowlton

From headquarters in New York, D. S. Bender covers the New England Telephone and Telegraph Company, the Southern New England Telephone Company and the New Jersey Bell Telephone Company, and A. M. Elliott the four areas of the New York Telephone Company. Mr. Bender, a 1923 graduate of Rensselaer Polytechnic Institute, came to the field engineering group in 1926, after instructing in mathematics and science for three years at the University of Cairo, Egypt. Mr. Elliott received his degree from the Carnegie Institute of Technology in 1921, and became associated with radio work in Arizona. In 1923 he entered the Western Electric Company and four years later was transferred to the Systems Development Department. His present assignment dates from August of this year.

The Bell Telephone Company of Pennsylvania and the Chesapeake and Potomac Telephone Company are served from Philadelphia by W. K. St. Clair. Since his graduation from the University of Montana in 1922, Mr. St. Clair has been continuously connected with engineering inspection work.

Atlanta is the field engineering headquarters for the Southern Bell Telephone and Telegraph Company; as his first field engineering assignment, T. L. Oliver is handling the work in this territory. Mr. Oliver came to the Inspection Engineering Department from the Systems Development Department, which he joined after receiving an engineering degree from Virginia Polytechnic Institute in 1923.

The Ohio Bell Telephone Company and the Cincinnati and Suburban Bell Telephone Company areas are handled by G. Garbacz, whose Bell System experience includes work with the New England Telephone and

Telegraph Company and the Western Electric Company. Mr. Garbacz was graduated from the Milwaukee School of Engineering in 1922.

R. C. Kamphausen began his work in telephony in 1914 with the Cincinnati and Suburban Bell Telephone Company, remaining with that company until the entry of the United States into the World War. Upon his discharge from the Signal Corps in 1919, he entered the University of Cincinnati to complete previous work, receiving the E. E. degree in 1921. Mr. Kamphausen is now stationed in Detroit, for contact with the Indiana Bell Telephone Company and the Michigan Bell Telephone Company.

Chicago is the headquarters for the field engineer covering the Illinois Bell Telephone Company and the Wisconsin Telephone Company areas. This position is filled by I. W. Whiteside, who also has had considerable experience in inspection engineering. After graduation in 1922 from the University of Colorado, he took up central office inspection work at West Street and was later given field engineering assignments in Seattle, Cleveland and Detroit.

H. W. Nylund is the field engineer for the Southwestern Bell Telephone Company area, with headquarters in St. Louis. He was graduated from Iowa State College in 1925, and worked with the Systems Development Department until early in 1927 when he was assigned to his present duties.

The largest geographical area handled by one field engineer is that served by the Northwestern Bell Telephone Company and the Mountain States Telephone and Telegraph Company. W. E. Whitworth is assigned to this territory, and covers it from headquarters in Omaha. Mr. Whitworth also came to this work from the Systems Development Department, which he joined after graduation from the University of Wisconsin in 1924.

The three areas of the Pacific Telephone and Telegraph Company are covered by J. A. St. Clair, with headquarters in San Francisco. On obtaining his degree from the University of Colorado in 1922, Mr. St. Clair entered the Western Electric Company for central office inspection work, transferring to the Inspection Engineering Department of the Laboratories in 1924.

Introducing the College Man

THE Bell System, approaching the 400,000 mark in personnel, takes pride in the fact that the history of its development reveals growth at an ever increasing rate, and advancement based on sound engineering principles. The laboratory development and research activities of the system are centered in Bell Telephone Laboratories.

It is in a measure through this organization that the system insures the meeting of an obligation to which it has pledged itself. As expressed by President Gifford,* " . . . It is fundamental in our plan of organization to have at headquarters and in our laboratories several thousand people whose sole job is to work for improvement. They are engaged in studying what is used in the telephone business and how it is used and endeavor to find a better thing or a

* *Addressing the National Association of Railroad and Utilities Commissioners. See* BELL LABORATORIES RECORD, *Volume* 5, *page* 75.



Top Row: W. E. Reichle, Michigan; J. B. Bishop, Cornell; L. E. Abbott, Brooklyn Poly.; J. F. Byrne, Ohio State; A. S. King, Lehigh; L. W. Curtis, Idaho; H. I. Romnes, Wisconsin; L. A. Woote, North Carolina; E. J. Bonnesen, Iowa State; A. C. Beck, R. P. I.; T. E. Davis, Arizona; E. Mottram, Columbia; G. N. Loomis, Yale; A. A. Burgess, Yale; H. L. Quam, South Dakota State; B. Stallard, Kansas; A. L. Hopper, R. P. I.

Middle Row: P. B. Drake, Virginia Poly.; C. R. Eckberg, Minnesota; E. E. Thomas, University Coll. Wales, G. B.; A. L. Hall, Worcester Poly.; V. E. Reilly, N. Y. U.; F. A. Coles, California; W. A. Yager, Union; A. G. Bousquet, Tufts; E. Lakatos, Stevens; E. A. Bescherer, Purdue; A. W. Hawley, Yale; R. A. Dexereux, Columbia; M. C. Gauthier, Pratt Institute; D. B. Herrmann, C.C.N.Y.; B. F. Lynip, Jr., California

Bottom Row: R. B. Mears, Penn. State; D. J. Salley, North Dakota; M. S. Gudger, Georgia Tech.; D. C. Smith, Union; A. Decino, Colorado; C. D. Owens, Indiana; F. I. Smith, Coe; H. M. Knapp, Stevens; E. J. Donohue, Stevens; W. R. Neisser, Bucknell; C. B. Green, Ohio State; R. M. Kalb, Ohio State; J. F. Dillinger, Ohio State; W. H. Bartosh, Penn. State



Top Row: M. W. Bryant, Washington State; S. M. Sutton, Missouri; A. E. Sayler, Southern California; E. A. Schramm, Washington; A. M. Koerner, Minnesota; B. Foulds, Yale; C. B. Dalphin, Fordham; J. H. Zimmer, Cornell; C. T. Owlett, Cornell; D. W. Grant, Kansas State; R. L. Taylor, Washington State. Middle Row: P. A. Lasselle, Oregon; W. M. Goodall, California Tech.; C. L. Watson, Stanford; K. G. Jansky, Wisconsin; H. W. Augustadt, North Dakota; W. E. Burke, Oregon State; W. F. Brown, N. Y. U.; W. H. Stephens, Nebraska; F. E. Masek, Kansas State; E. E. Wright, Brooklyn Poly.; D. T. Sharpe, Iowa State; J. D. Tebo, Johns Hopkins. Bottom Row: B. E. Stevens, Minnesota; E. S. Dobson, Lafayette; F. S. Wolport, Newark Col. of Eng.; A. L. Samuel, M. I. T.; E. E. Mott, M. I. T.; C. F. Benner, Purdue; J. A. Bagdon, Brown; A. B. Crawford, Ohio State; S. Bobis, Grenoble, France; E. J. Basch, Union

better way. . . . progress is assured by having a large group of scientists and experts devoted exclusively to seeking ways of making the service better and cheaper."

In order that Bell Telephone Laboratories may cope with the ever increasing demand placed upon it for engineering advice many new men are encouraged each year to come from educational institutions and elsewhere and affiliate themselves with us. These young men quite naturally feel that our business is extremely complex, and that a considerable groundwork of information is necessary before they can take up their new duties with confidence. To help lay this foundation it is the custom of our Educational Department to conduct a brief but intensive introductory survey during the summer of each year.

During this instruction the general organization of the Bell System is explained in order to present the purpose of the Laboratories and its place in that system. This is followed by a general description of departmental functions and activities. Members of the technical staff represent their own departments in explaining their particular field, the problems encountered and their facilities for solving them. These talks are often followed by visits to appropriate laboratories where further explanations and demonstrations are given. Trips to telephone central offices of both manual and dial types are conducted to show typical examples of the conditions under which service is rendered to the public as a result of activities in the Laboratories. Having described the many parts of the business and,



Top Row: C. A. Grierson, M. I. T.; S. S. Neill, Miss. A. & M.; J. O. Israel, Lafayette; F. E. Blount, Oregon State; E. T. Pierce, Yale; B. Page, Brown; J. H. Shepard, Jr., Brown; W. M. Sharpless, Minnesota; W. K. Caughey, Stevens; C. B. Aiken, Harvard; J. W. Bailey, Cornell; H. W. Baltazzi, U. S. Naval Academy; L. H. Whitman, Michigan; J. A. Hitz, Pratt Institute; B. A. Fairweather, Wisconsin. Middle Row: W. E. Dorland, Cornell; I. L. Bateman, Southern California; J. R. Fisher, Brooklyn Poly.; J. F. Eckel, Carnegie Tech.; J. V. Kurtinaitis, Illinois; A. P. Huchberger, Columbia; D. M. Black, Kansas; C. E. Nelson, Brigham Young; P. H. Smith, Tufts; R. J. Fluskey, N. Y. U.; C. L. Frederick, George Washington; H. E. Mendenhall, California Tech.; C. H. Prescott, California Tech.; F. West, Johns Hopkins; E. D. Gibbs, Worcester Poly.; C. S. Knowlton, Lowell Institute. Bottom Row: A. T. McNeill, Wisconsin; E. M. Keillor, Michigan; M. L. Martin, Wisconsin; D. T. Bell, Georgia Tech.; E. C. Walsman, Ohio Wesleyan; M. A. Specht, Cornell; A. J. Tatarcuk, New Hampshire; H. Kahl, Washington State; P. H. Richardson, Harvard; E. H. Toney, Miss. A. & M.; W. R. Lundry, Iowa State; D. C. Lloyd, Delaware; J. E. Tarr, Maine

in so doing, having shown their interrelationship, the survey is concluded by a summary of company policies and of opportunities provided for continued study. Each new member is assigned to a type of work consistent with his training and propensities before he enters the survey in order that during the course he may be alert for those bits of information which will aid his orientation in his chosen field of work.

The group just issuing from the introductory course, like its predecessors, represents educational institutions in every section of the United States and in some foreign countries as well as various other departments of the Bell System. Wide representation is distinctly advantageous in that it brings together men with common interests but with varied backgrounds of experience. The Associated Operating Telephone Companies by keeping in close contact with the engineering colleges and describing our work to qualified students have greatly assisted our Personnel Department in the selection of new employees.

The Laboratories expects these new members to bring with them the habit of study and the susceptibility to instruction which has characterized their previous training and hopes that they will utilize the facilities offered for further study and advancement.

They will soon begin to realize — what those of us who are older at the business know so well — that employment marks not the end of one's education but rather its beginning. On its side, the Laboratories will not forget that although dedicated to the achievement of distinctly practical ends, it must cooperate with the members of its organization in broadening their knowledge of electrical communication. To this end and to supplement the introductory courses, many other courses both in and out-of-hours are offered to those who have the necessary background.

Key Town Selling

Members of the Laboratories have probably seen the advertisements of the "key town selling" plan recently placed by the American Telephone and Telegraph Company in prominent magazines. The plan encourages the use of the telephone to sell, from bases of operation in market centers. Specifically to facilitate this use, the Bell System offers general and regional key town maps, dividing the country in such a way as to afford maximum convenience to telephonic coverage from recognized centers of distribution. From business-classified directories, a travelling representative can compile a call list of logical prospects, then file it in advance for rapid completion by a specially assigned operator through the "sequence" calling service. Telephone Companies are providing in key town exchanges comfortable rooms from which salesmen can make these calls, and have instituted a credit plan enabling them to have their telephone expenses charged to their home offices. Organizations are recognizing that large scale production economies must not be offset by large scale selling expenses; the response to the offer of key town service has been gratifyingly large.



JOHN J. LYNG

"Effective October first J. J. Lyng has been appointed Vice-President of Electrical Research Products, Incorporated.

"It is with a feeling of regret, and yet of pleasure that I make this announcement, regret because we lose the direct advice and competent counsel of a friend long associated with our particular business, and pleasure because of the general advancement that this move means to him personally. All of his friends in the organization, and he has many, join with me, I know, in assuring him of our continued friendship and of our assistance in the success of his undertaking, which will be intimately associated with our work for the Electrical Research Products, Incorporated." E. B. CRAFT, *Executive Vice-President.*

News Notes

MR. JEWETT was present at a luncheon and meeting of the Corporation of Massachusetts Institute of Technology at Boston on October 10. He also attended the Presidents' Conference at Yama Farms, New York, from October 2 to 8. On October 18 he spoke on "The Ideals, Opportunities and Difficulties of the Engineering Career" at a public lecture given at Dartmouth College.

MR. CRAFT spoke at the General Staff Luncheon of the Western Electric Company on October 5, on "Some Aspects of Aircraft Communication Development."

WITH THE RESIGNATION of J. J. Lyng to become Vice-President of Electrical Research Products, Incorporated, R. L. Jones has been appointed Director of Apparatus Development. With the Apparatus Development Department there will be merged the work, already under the direction of Mr. Jones, of the Outside Plant Development Department and of the Inspection Engineering Department. Reporting to Mr. Jones in charge of the latter will be G. D. Edwards, Inspection Engineer.

AT THE OPENING MEETING of the Colloquium for the year, K. K. Darrow spoke on "The Raman Effect", and Dr. D. P. Mitchell of Columbia University told briefly of results of his experimental work in that field. The meeting closed with a talk by H. E. Ives on "Parallax Relief Pictures" and a demonstration of pictures produced. Preceding the evening's program, the president, W. S. Gorton, appointed R. V. L. Hartley, E. C. Wente and A. L. Johnsrud as the Committee on Procedure for the season. At the following meeting, on October 22, R. M. Bozorth spoke on "Discontinuities in Magnetization", telling of recent experimental results obtained by him in a quantitative investigation of the Barkhausen effect in permalloy and in single crystals of iron.

THE AMERICAN SOCIETY FOR STEEL TREATING held its annual convention at Philadelphia on October 10 and 11. Those present from the Laboratories included W. Fondiller, H. N. Van Deusen, H. A. Anderson, J. R. Townsend, C. R. Wohrman and C. H. Greenall. While in Philadelphia, Messrs. Anderson, Greenall, Townsend and Van Deusen also attended the Fall Meeting of the Die Casting Committee of the American Society for Testing Materials.

APPARATUS DEVELOPMENT

B. FREILE was in Chicago during the week of September 17, to confer with engineers of the Automatic Electric Company and Hawthorne Works on modifications in the design of step-by-step apparatus.

N. BISHOP visited Winnipeg during the week of October 9 to supervise the testing of a 105-C radio telephone broadcasting equipment recently sold to the Provincial Government of Manitoba.

H. H. GLENN attended a conference of the Textile Committee of the American Society for Testing Ma-

terials in Washington on October 11.

A. H. W. Kaack observed a new method of hardness testing, using the monotron, at the Shore Manufacturing Company in Jamaica.

F. F. Lucas delivered a paper on "Further Observations on the Microstructure of Martensite" before the Annual Convention of the American Society for Steel Treating in Philadelphia on October 10. He addressed the New York Microscopical Society on October 19, on "High Power Metallurgy and the Ultra-violet Microscope."

Mr. Lucas was appointed a member of the consulting staff, Ordnance Department, United States Army, and spent October 2 to 5 at the arsenal at Watertown, Massachusetts, in connection with his duties. He later discussed with members of the staff of the Harvard Medical School the application of the ultra-violet microscope to cancer research.

J. C. Wright and N. Insley spent the last week of September at Hawthorne in connection with the development of switchboard lamps.

W. E. Mougey was elected to membership in Edward J. Hall Chapter, Telephone Pioneers of America, on October 9.

C. A. Webber visited Philadelphia October 5 to discuss with representatives of the Bell Telephone Company of Pennsylvania splicing of distributing frame wire.

H. N. Van Deusen lectured October 5 in the Auditorium before the members of the General Apparatus Development Group on the nature and method of solving of materials problems in the Laboratories.

W. V. Wolfe, C. F. Boeck and J. D. Sarros attended the Convention of the Pacific Coast Section of the A. I. E. E. from August 28 to 31. Mr. Wolfe and Mr. Sarros were the co-authors of a paper presented at that time, entitled "Some Problems in Power Line Carrier Telephony, and Apparatus Developed to Meet Them."

E. C. Sofio visited Hawthorne from September 10 to 13 in connection with the manufacture of disc recording machinery.

R. V. Terry supervised the installation of a new type universal base for reproducing synchronized sound pictures, at the Convention of the Society of Motion Picture Engineers at Lake Placid. He also visited the Bausch and Lomb factory at Rochester.

Outside Plant Development

C. S. Gordon and C. A. Chase visited the plants of the Henry L. Scott Company and the New England Butt Company of Providence on September 20 to select equipment for a wire-testing laboratory.

F. D. Powers, with J. H. Gray of the American Telephone and Telegraph Company, visited Providence on September 18 in connection with the development of cotton sleeving.

V. B. Pike and D. T. Sharpe conducted pressure tests on a toll cable installed at Reading, Pennsylvania, on September 25 and 26.

E. St. John visited Harrisburg, Pennsylvania, on September 13 to discuss matters relating to the use of electrically welded steel ladders.

Patent

Mr. Jewett addressed the first Patent Department luncheon of the season, held at the Fifth Avenue Hotel on October 16.

G. M. Campbell visited Camden.

New Jersey in connection with the prosecution of applications for patent. E. V. Griggs, W. C. Kiesel, J. F. McEneany, G. T. Morris and T. P. Neville visited Washington for the same purpose.

DURING JULY, AUGUST AND SEPTEMBER, applications for patent were granted to the following members of the Laboratories staff:

G. A. Anderegg	M. B. Kerr
H. C. Baumann	A. W. Kishpaugh
H. S. Black (2)	J. J. Kuhn
J. H. Bower	C. D. Lindridge
O. E. Buckley	G. A. Locke
H. C. Caverly	W. P. Mason
I. B. Crandall	R. C. Mathes
A. M. Curtis (2)	D. T. May
J. F. Dahl	C. G. McCormick
G. W. Elmen (2)	L. A. Mortimer
H. T. Friis (2)	E. L. Norton
M. E. Fultz	A. A. Oswald
J. C. Gabriel	E. Peterson
J. J. Gilbert	P. H. Pierce
E. V. Griggs	L. F. Porter
A. E. Hague	H. O. Siegmund
R. W. Harper	K. O. Thorp
H. C. Harrison (2)	E. B. Wheeler
R. A. Heising (2)	J. H. White
F. A. Hubbard	R. R. Williams
H. E. Ives (2)	S. B. Williams
M. J. Kelly	W. V. Wolfe
J. C. Wright	

SYSTEMS DEVELOPMENT

F. B. ANDERSON AND A. J. PASCARELLA visited the toll repeater station at Harrisburg, Pennsylvania during the week of September 15.

J. B. SHIEL AND F. VAN VOORHIS investigated the installation of 84-F interrupter equipment at Watertown, Connecticut.

W. A. PHELPS, J. L. HYSKO, R. B. STEELE AND W. F. MALONE have completed tests to provide additional telegraph facilities for the Key West-Havana cable.

J. A. MAHONEY visited Toronto, Smiths Falls and Montreal, Canada, in connection with the introduction of carrier telegraph equipment on the Canadian Pacific Railway System.

A. E. PETRIE observed tests on new gas engines at the factory of the Buffalo Gas Engine Company at Buffalo, New York.

J. L. LAREW inspected the new power equipment at the repeater stations on the Washington-Atlanta cable at Greensboro, Burlington, Durham and Norlina, North Carolina.

J. H. SOLE visited the General Electric Company at Pittsfield, Massachusetts, on September 15 and 17.

J. W. WOODWARD discussed the new Los Angeles Toll Project with engineers of the Pacific Telephone and Telegraph Company at Los Angeles.

RESEARCH

D. G. BLATTNER, H. A. FREDERICK, H. C. HARRISON AND W. C. JONES visited the Victor Talking Machine Company at Camden on October 2.

R. E. WATERMAN made a study of the preservation of telephone poles at Bridgeton, New Jersey, on September 17.

J. E. HARRIS AND E. E. SCHUMACHER observed the manufacture of cable sheath at Hawthorne during the week of September 16.

C. W. BORGMANN, R. M. BURNS, B. L. CLARKE, C. L. HIPPENSTEEL, A. R. KEMP, P. A. LASELLE, J. A. LEE AND R. R. WILLIAMS attended a meeting of the American Chemical Society at Swampscott, Massachusetts during the week of September 10.

R. M. BURNS attended meetings of the American Electro-Chemical Society at Charleston, West Virginia, on September 21 and 22. He subsequently made a study of metal finishes at Hawthorne.

C. J. DAVISSON gave a paper "Scattering of Electrons by a Crystal of Nickel" before the Glasgow meet-

ing of the British Association for Advancement of Science on September 11, describing the experiments performed by himself and L. H. Germer.

K. K. DARROW addressed the Colloqium of the Washington Square College of New York University on October 10, on "The Raman Effect and the Corresponding Effect with Electrons."

WILLIAM D. NOBLE died at his home at Newark on Saturday, September 15. Mr. Noble joined the Bell System on November 27, 1917, and for a number of years had been a member of the group interested in the development of transmission instruments.

A. C. WALKER was present at a conference of the Textile Committee of the American Society for Testing Materials in Washington, October 11.

H. E. IVES described television apparatus and its operation at a meeting of the Montclair Rotary Club on October 30.

GENERAL STAFF

S. P. GRACE addressed the regional convention of the American Institute of Electrical Engineers at Atlanta, Georgia, on October 29, on "Delayed Speech and Other Recent Discoveries and Inventions of Bell Laboratories."

JOHN MILLS spoke to the faculty and students of the Massachusetts Agricultural College at Amherst, Massachusetts, October 25, on the subject of balanced rations of work. On September 24 he described to the Society of Motion Picture Engineers in convention at Lake Placid the work and organization of the Laboratories. Among the films shown to that Society was "The Magic of Communication." Mr. Mills also spoke at the annual banquet of the Society.

RICHARD MALZER, a journeyman instrument maker in the Engineering Shop, died on October 6. He entered the Laboratories in 1922, and was a graduate of the Instrument Makers' Apprentice Course.

FRANK W. ANDERSON, an assistant foreman in the Building Shop, died on October 20. He had been a member of the Laboratories since 1923.

W. C. F. FARNELL accompanied G. K. Thompson of A. T. & T. on a trip to Washington on October 23 to represent the Bell System in presenting a sectional model of a telephone transmitter and receiver to the National Museum of the Smithsonian Institution.

* * * *

A TYPOGRAPHICAL ERROR in the October RECORD should be noted. In the article "The Nobel Laureates" by Karl K. Darrow, page 40, right-hand column, line 16 *et seq.* should read:

. . . . . . Michelson, however performed an experiment from the result of which there was no possibility of escape . . . .

Bell Laboratories Club

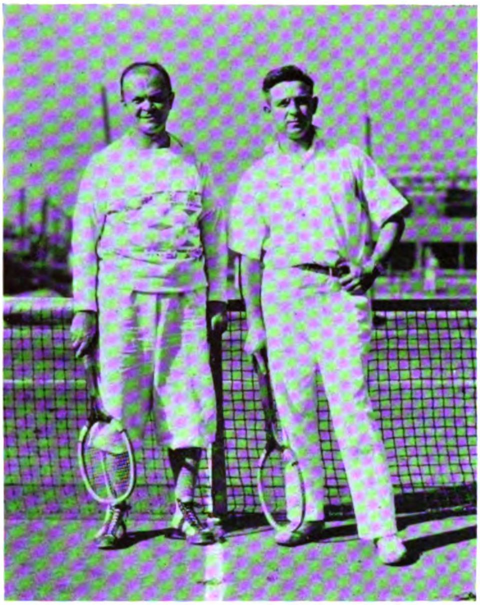
THERE is to be a Christmas poster contest this year open to all members of the organization. Those interested in participating in the contest should submit their posters to D. D. Haggerty by December 1. All posters should measure twelve by sixteen inches, be made in not more than three colors, and have space for a Christmas greeting which will be inserted after the winning entry has been chosen. The posters will be judged by an impartial committee and one or more of the best will be reproduced and displayed on the company bulletin boards during the holiday season. A ten-dollar gold piece is offered as a prize for the winning poster.

Tennis

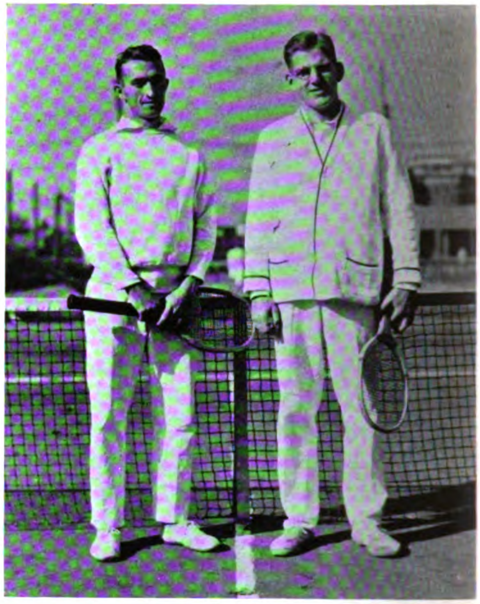
Saturday, September 29, for which the first two rounds of the men's doubles tennis tournament were scheduled, saw a morning conference in Dave Haggerty's office, pondering the leaden skies. The conclusion was that the day would have to do, and thirty-six contestants, assembling in the afternoon, deployed without debate over the Mammoth Courts and started lifting the ball past the occassional raindrop. Aside from intermissions for wiping spectacles, the



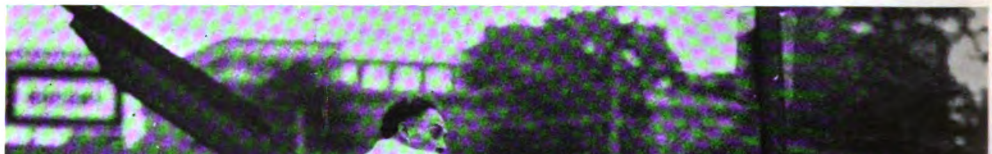
H. T. Reeve follows through a drive.



P. Norton and W. E. Stevens



A. M. Elliott and F. S. Entz



R. H. Wilson takes it on his backhand

weather called forth during the first round only grim earnestness and spirited determination. The hardest fought and most brilliant of the first round matches was probably that of W. C. Lamoreaux and E. M. Tolman, playing together for the first time, against H. T. Reeve and R. H. Wilson. Lobbing, and Wilson's spectacular gets at net, kept the new combination hard at work through three sets. Fast and sturdy tennis finally brought Lamoreaux and Tolman out ahead.

Most of the first-round victors decided to let well enough alone and abandoned the field in favor of dry shelter. But K. S. Johnson and M. B. Kerr, the redoubtable left-handers, and W. E. Stevens with his partner, the veteran P. Norton, who had won their first-round matches in straight sets, recklessly agreed to have at one another. And Lamoreaux and Tolman advanced on A. M. Elliott and F. S. Entz, who had beaten R. M. Bozorth and J. M. Eglin somewhere far from the spectators. Mr. Johnson's chops and kills and Mr. Norton's well-diversified playing made their match nip and tuck. The opponents won game for game until the score stood two all, then four games and the first set went to Johnson and Kerr. Stevens and Norton came back to take the second set 6-4.

About this time the rain began to come down with a will, soaking the doughty players' rackets and plastering with mud the hard-working tennis balls. But the undaunted combatants merely took fresh balls and courts and continued.

At last, with the score two all in the third set, Mr. Norton suggested postponing settlement, out of regard for the rivulets on Mr. Kerr's spectacles. The other match, spectacles and all, persisted to the bitter end, Elliott and Entz beating Lamoreaux and Tolman 6-4, 6-3.

Next Saturday, and the Friday following, beamed more favorably on the Mammoth Courts and saw the completion of all but the finals. E.



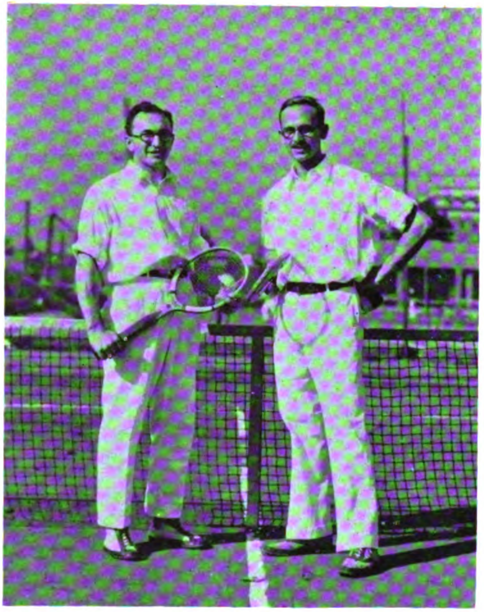
P. Norton picks up a low one

H. Chatterton and J. Blanchard, barging through all comers in straight sets, reached the final bracket by defeating H. I. Miller and W. Kuhn, 6-4, 6-3, then taking out H. M. Yates and P. Kuhn, 6-1, 6-2, 6-3. Johnson and Kerr allowed Stevens and Norton only one more game in their interrupted match and then struggled past Elliott and Entz, 6-3, 0-6, 4-6, 6-4, 6-2.

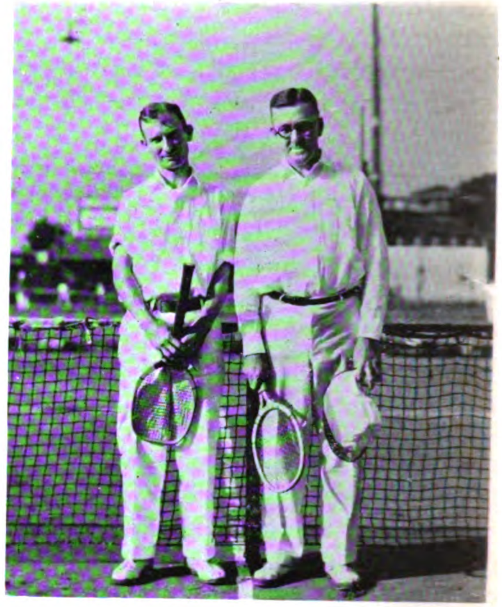
The finalists met in the stiff breeze of October 20; Johnson and Kerr broke through the steady play of Chatterton and Blanchard, 6-3, 6-3, 7-9, 6-2, for the championship.

Basketball

The Bell System League will open the 1928-29 season on Monday evening, November 12, at Stuyvesant



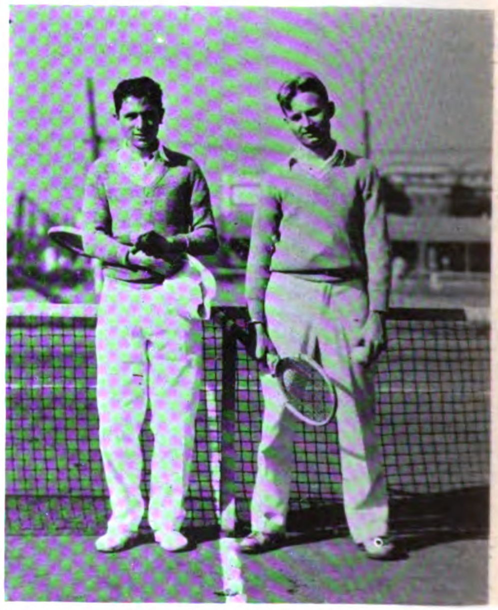
M. A. Boccalery and D. H. Pennoyer



J. Blanchard and E. H. Chatterton



K. S. Johnson and M. B. Kerr



W. Kuhn and H. I. Miller

High School, First Avenue and Fifteenth Street, New York. League games will be played on Monday and Friday evenings at Stuyvesant High School and on Wednesday evenings at Erasmus Hall High School, Church and Flatbush Avenues, Brooklyn. Two games will be played each evening and there will be dancing after each game. Season tickets which will admit the holder to all twenty-seven sessions of the league will cost one dollar, tickets for individual games costing twenty-five cents. The Basketball Committee hopes that last season's attendance will be not only sustained but surpassed. For further information, call D. D. Haggerty, Extension 542.

Golf

The regular Fall Golf Tournament was held at the Salisbury Country Club on Saturday, September 22, but the entire tournament was played on one day instead of two, as heretofore. This method proved very popular, since the entries exceeded by far those of any previous fall tournament. The seventy-four players were divided into three classes on the basis of handicaps.

Each class played for prizes of equal value. The low gross prize in each class was a wrist watch. In Class A, G. E. Kellogg and H. W. Wood tied for the prize with an eighty-seven and in the subsequent play-off Kellogg won. R. C. Koernig won the watch in Class B with a ninety-three and J. F. Dalton was low man in Class C with a one hundred and ten. The low net prize, a Parker desk set, was won in Class A by R. E. Collis while the winners of similar prizes in Classes B and C were E. Peterson and F. A. Korn, respectively. The second low net prize in Class A was a musical water jug, won by F. F. Farnsworth. W. F. Johnson received a golf sweater as the winner of second low net in Class B, and a dozen U. S. Royal Golf Balls, donated by Alex Taylor and Co., were awarded to T. P. Ingram as the second low net prize in Class C. Due to the fact that there were so many more entries in Classes B and C than there were in Class A, a third low net prize was added in these classes. A. N. Gray received a half-dozen Kroflite Golf Balls as the third low net winner in Class B, and E. J. Daniels and C. L. Goodrum who tied in third position for Class C, received a pair of golf stockings each.

Bowling

The Bowling League began its season on Friday evening, September 28, at Dwyers Manhattan Alleys, 1680 Broadway. "D" league was increased from four to eight teams, the Committee having received entries from over two hundred men wishing to bowl as regulars. This means that for the coming season the Club will have thirty-two teams competing for a total of twenty-eight weeks.

In addition, there were received the names of one hundred men who wish to bowl as substitutes. Men may have their names placed on the substitute list by communicating with R. L. Quass.

All league games will start promptly at 5:45. The cost of each evening's bowling will be seventy-five cents per man, which is thirty-five cents less than the fee charged last season.

Women's Basketball

The prime objective of the Women's Basketball Squad, now practicing

each Monday night, is the formation of a Bell Laboratories team to be entered in the Bell System Basketball League. The first game is on November 14. This and subsequent games will be played each Wednesday night prior to the Men's League game, at Erasmus Hall High School, Flatbush and Church Avenues, Brooklyn. Admission is covered by the season ticket issued by the Men's League.

Glee Club

The Glee Club held its first rehearsal of the season on Wednesday evening, November 17, under the direction of Mr. V. S. Richards, a professional instructor. Ada Van Riper and P. H. Betts will be glad to furnish further information to those interested in joining this group, and rehearsals will be held each Wednesday evening at 5:10 in the Women's Rest Room.

Indoor Golf

Another Women's Indoor Golf Tournament will be held on Tuesday, December 4, the place to be announced later.

Club Calendar for November

THURSDAY, 1: Basketball, Men, Labor Temple, 5:30
Orchestra Rehearsal, 11th floor Rest Room, 5:30

FRIDAY, 2: Dance, Hotel McAlpin; Bridge, Women, 11th floor Rest Room, 5:10

MONDAY, 5: Basketball, Women, St. Lukes gymnasium, 5:30
Bridge, Men, Room 275, 6:00
Women's Swimming Class, Carroll Club, 7:00

TUESDAY, 6: Hike, Englewood to Alpine

WEDNESDAY, 7: Women's Swimming Class, Carroll Club, 5:30
Glee Club, 11th floor Rest Room, 5:30

THURSDAY, 8: Basketball, Men, Labor Temple, 5:30
Orchestra Rehearsal, 11th floor Rest Room, 5:30

FRIDAY, 9: Bowling, Men, Dwyers Manhattan Alleys, 5:45
Bowling, Women, Dwyers Manhattan Alleys, 5:45
Bridge, Women, 11th floor Rest Room, 5:10
Athletic Dancing Class, Women, Louis Vecchio Studio, 5:30

MONDAY, 12: Basketball, Women, St. Lukes gymnasium, 5:30
Basketball, Men, Bell System League Tournament, Stuyvesant High School, 8:30; dancing after game
Bridge, Men, Room 275, 6:00
Women's Swimming Class, Carroll Club, 7:00

TUESDAY, 13: Basketball, Men, Labor Temple, 5:30

WEDNESDAY, 14: Glee Club, 11th floor Rest Room 5:10
Women's Swimming Class, Carroll Club, 5:30
Basketball, Men and Women, Bell System League Tournament, Erasmus Hall High School, 7:30; dancing after game

THURSDAY, 15: Basketball, Men, Labor Temple, 5:30
- Orchestra Rehearsal, 11th floor Rest Room, 5:30

FRIDAY, 16: Bowling, Men, Dwyers Manhattan Alleys, 5:45
- Bowling, Women, Dwyers Manhattan Alleys, 5:45
- Bridge, Women, 11th floor Rest Room, 5:10
- Athletic Dancing Class, Women, Louis Vecchio Studio, 5:30
- Basketball, Men, Bell System League Tournament, Stuyvesant High School, 8:30; dancing after game

SATURDAY, 17: Hike, along Bronx River Parkway

MONDAY, 19: Basketball, Women, St. Lukes gymnasium, 5:30
- Basketball, Men, Bell System League Tournament, Stuyvesant High School, 8:30; dancing after game
- Bridge, Men, Room 275, 6:00
- Women's Swimming Class, Carroll Club, 7:00

TUESDAY, 20: Basketball, Men, Labor Temple, 5:30

WEDNESDAY, 21: Glee Club, 11th floor Rest Room, 5:10
- Women's Swimming Class, Carroll Club, 5:30
- Basketball, Men and Women, Bell System League Tournament, Erasmus Hall High School, 7:30; dancing after game

THURSDAY, 22: Basketball, Men, Labor Temple, 5:30
- Orchestra Rehearsal, 11th floor Rest Room, 5:30

FRIDAY, 23: Bowling, Men, Dwyers Manhattan Alleys, 5:45
- Bowling, Women, Dwyers Manhattan Alleys, 5:45
- Bridge, Women, 11th floor Rest Room, 5:10
- Athletic Dancing Class, Women, Louis Vecchio Studio, 5:30
- Basketball, Men, Bell System League Tournament, Stuyvesant High School, 8:30; dancing after game

SUNDAY, 25: Hike along Mianus River

MONDAY, 26: Basketball, Women, St. Lukes gymnasium, 5:30
- Basketball, Men, Bell System League Tournament, Stuyvesant High School, 8:30; dancing after game
- Bridge, Men, Room 275, 6:00
- Women's Swimming Class, Carroll Club, 7:00

TUESDAY, 27: Basketball, Men, Labor Temple, 5:30

WEDNESDAY, 28: Glee Club, 11th floor Rest Room, 5:10
- Women's Swimming Class, Carroll Club, 5:30
- Basketball, Men and Women, Bell System League Tournament, Erasmus Hall High School, 7:30; dancing after game

FRIDAY, 30: Bowling, Men, Dwyers Manhattan Alleys, 5:45
- Bowling, Women, Dwyers Manhattan Alleys, 5:45
- Bridge, Women, 11th floor Rest Room, 5:10
- Athletic Dancing Class, Women, Louis Vecchio Studio, 5:30
- Basketball, Men, Bell System League Tournament, Stuyvesant High School, 8:30; dancing after game

Telephone Service Between the United States and Spain

On October 13th telephone service between the United States and Spain was inaugurated by conversation between President Coolidge in Washington and King Alfonso XIII in Madrid. Proceeding by the usual transatlantic routes between Washington and London, their voices passed over land lines of the British General Post Office, a submarine cable in the British Channel, lines of the French Ministry of Posts and Telegraphs between Boulogne and the Spanish border, and lines of the National Telephone Company of Spain, a total distance of 6,500 *miles. News which it required Columbus's returning ships two months to bring to Spain from the New World can now be communicated in about one-fifth of a second.*

Telephone Stock

American Telephone and Telegraph Company stock totalling $1,000,000 *in market value has been delivered during the past year to members of the Laboratories. This cost its owners about* $600,000 *in actual payments; the American Company added to the payments an interest allowance of about* $70,000.

You, as a member of the Bell System, can subscribe to the stock at $130 *per share, of which* $115.75 *will be deducted from your pay and* $14.25 *will be paid you as interest by the American Company. Thus purchased, the investment will give you a return of* 6.9% *on the price, or* 7.7% *on the amount actually deducted from your pay.*

Your opportunity is enviable; you can make no mistake in availing yourself of the Stock Plan.

BELL LABORATORIES RECORD

THE DECIBEL
By R. V. L. Hartley

DEVELOPMENT OF THE IMPEDANCE BRIDGE
By S. J. Zammataro

CLUB REPORT, 1928

CLUB ELECTIONS

DECEMBER 1928 VOL. 7 NO. 4

Bell Laboratories Record

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Bell Laboratories Record

Volume Seven DECEMBER, 1928 *Number Four*

"TU" Becomes "Decibel"

By R. V. L. HARTLEY
Transmission Research Director

SOME years ago the mile of standard cable was displaced as the unit of transmission in the Bell System by a younger brother. This newcomer in the family of transmission units, being without a given name, adopted that of the family and became known as the "transmission unit" or "TU". It has now been given the more distinctive title of "decibel", commonly abbreviated "db". The prefix "deci" indicates one-tenth, while "bel" is derived from the name of Alexander Graham Bell.

The members of the transmission unit family resemble each other in that they all measure the logarithm of the ratio of two powers, currents or other quantities which express the magnitudes of the waves being compared. This is a desirable property from two standpoints. First, it insures that two sounds of the same general nature and quality which differ by a given number of transmission units have the same difference in loudness regardless of their absolute loudness. The difference in loudness of two sounds may be measured by the number of intermediate steps that can be distinguished in passing from one loudness to the other. Within the limits of accuracy of Weber's law, in order to produce a recognizable increase in loudness, the intensity must be multiplied by a factor which is independent of the actual intensity. Hence, the number of recognizable steps is equal to the number of times which the smaller intensity must be multiplied by this factor to give the larger. This is the exponent to which the factor must be raised to equal the ratio of the two intensities, and by definition is the logarithm of the ratio of the intensities to a base equal to the minimum recognizable intensity ratio. It follows, therefore, that the logarithm of the intensity ratio to any base will always be proportional to the difference in loudness and so a logarithmic unit becomes a suitable measure by which to express the effect of a transmission system on the loudness of the received sound.

In the second place, the use of a logarithmic unit facilitates the deduction of the overall transmission properties of a system from those of its parts. Suppose, for example, that

some telephone system is being compared with a reference system. We may picture the test system as being derived from the reference system by successively replacing each part. Each change causes the received power to change in a particular ratio. By multiplying together all these ratios we get the ratio in which the power is changed in going from the reference to the test system. If, however, we measure the effect of each replacement by the logarithm of the corresponding ratio, we have only to add the effects of the individual steps to get the overall effect.

The members of the family, while alike in being logarithmic, differ in the base to which the logarithm is taken. However we may go from one base to another by introducing the proper multiplying factor. Hence the difference between the various units is effectively one of size only. Among the units in use when the TU was chosen, the 800 cycle mile of standard cable is of such size that the number of miles is given by 10.56 $\log_{10} P_1/P_2$, where P_1 and P_2 are the two powers involved. For the so-called βl unit then in use in parts of Europe the number is $\frac{1}{2} \log_e P_1/P_2$, or what is equivalent, $\log_e J_1/J_2$, where J_1 and J_2 are the currents involved. (When currents are used it is assumed that they flow in equal impedances.) If we transform the βl unit to common logarithms the number is given by $1.151 \log_{10} P_1/P_2$. In order that the TU might be roughly equal to the "mile of standard cable," the size selected for the TU was so chosen that the number of TU is $10 \log_{10} P_1/P_2$.

In view of the desirability of the universal use of one unit for telephone transmission work, the Bell System took up this matter with various foreign telephone administrations and suggested that they consider the TU for this purpose. This led to considerable discussion as to the relative merits of a transmission unit based on common logarithms such as the

> *The International Advisory Committee unanimously recommends the following definitions*:
>
> The unit of transmission expresses the ratios of apparent or real power, of potentials or of currents in transmission systems. In practice, the number of units of transmission in a given case is expressed in terms of a logarithm.
>
> If it is a case of two powers P_1 and P_2, the number of units is,
> in the naperian system, $\frac{1}{2} \log_e|P_1/P_2|$;
> in the decimal system, $\log_{10}|P_1/P_2|$.
>
> If it is a case of two voltages V_1 and V_2 or of two currents J_1 and J_2, the number of units is,
> in the naperian system, $\log_e|V_1/V_2|$ or $\log_e|J_1/J_2|$;
> in the decimal system, $2 \log_{10}|V_1/V_2|$ or $2 \log_{10}|J_1/J_2|$.
>
> The naperian unit is called "neper". The decimal unit is called "bel". A decimal sub-multiple of these units may be used, as "decineper" and "decibel".

TU, and one based on natural logarithms such as the βl unit. Action was finally taken in the form of a recommendation by the International Advisory Committee on Long Distance Telephony of Europe to the effect that the use of both units be recognized as standard in Europe.

It was also recommended that distinguishing names be assigned to the two transmission units. For the βl unit, which is so defined that the number of units is given directly by the natural logarithm of a *current* ratio, the term "neper" was chosen in honor of John Neper,* who first conceived the idea of logarithms. In the case of the TU, however, the common logarithm of a *power* ratio is multiplied by ten to get the number of units. This suggests that the TU is in the nature of a derived unit and that the primary unit should bear the same relation to the common logarithm that the neper does to the natural logarithm. The name "bel" was accordingly assigned to this primary unit. Since the number of TU corresponding to a given ratio is ten times the number of bels, the TU itself is equal to one-tenth of a bel, and so it became the "decibel".

In view of this recommendation, the Bell System has decided to use the term "decibel" as a name for the transmission unit. The transition from the old to the new will naturally be a gradual one. There will be no occasion to make changes in existing apparatus or written material, but rather the db will replace the TU in new work.

* *While this spelling may appear unfamiliar, the form "Napier" is comparatively modern. The name appears to have been going through a transition during the mathematician's lifetime and while his signatures show a variety of spellings, he generally used the oldest form "Neper."*

The Comstock Prize

The National Academy of Sciences has awarded the Comstock Prize to Clinton J. Davisson, for experiments carried out in these Laboratories. This prize is given each five years for "the most important discovery or investigation in electricity or magnetism or radiant energy"; this year it amounts to $2,300. *It was granted "for experimental work demonstrating that under certain conditions electrons behave as trains of waves might be expected to behave."*

Presentation of the award was made at the Autumn Meeting held at Schenectady, November twentieth, by Dr. Thomas Hunt Morgan, President of the Academy.

Composite Telegraphy

By J. H. BELL
Systems Development Department

WHEN a business firm has considerable daily telegraph communication with one or more distant correspondents — perhaps branch houses or factories — handling its own telegraph communications becomes a much speedier and oftentimes more economical plan than the generally used message plan familiar to the public. A very large amount of telegraph business connected with banks, brokers, packers, news-distributing agencies, and large manufacturing corporations is handled in this manner, and nearly all of it passes over Bell System lines. The telephone company leases a telegraph channel or channels between the points desired, and installs apparatus in the lessee's offices. The lessee furnishes his own operators and may send as much telegraph traffic as the channel will carry.

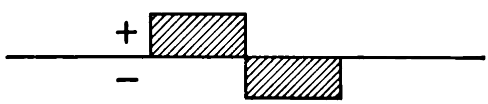


Fig. 1—With the printing telegraph a dot is formed by a short positive impulse followed immediately by an equal negative impulse

In the January, 1926 issue of the RECORD the writer described briefly the method of providing such telegraph facilities by means of the Carrier Telegraph System. It is the purpose of this article to describe another method of obtaining such facilities. This method, which is used extensively in the Bell System, is called "compositing." By "compositing" is meant the joint use of a circuit for telephone and telegraph purposes, the telegraph utilizing the frequency range below that required for the telephone and its signaling currents. How this is possible will be more evident after a consideration of some of the elements of telegraphy.

A telegraph sounder consists of an electromagnet with an armature pivoted at one end, which is drawn downward when current flows through the electromagnet and is restored by means of a fairly strong spring. The sounds made on the up and down strokes differ sufficiently to enable the trained ear of a telegraph operator to distinguish between them easily. If such a device be connected in series with a suitable source of electrical power and a key for closing and opening the circuit, a momentary depression of the key, termed a dot, will produce two clicks on the sounder, the down click and the up click. If the key be held down for a longer period, termed a dash, the time interval between the down and the up clicks will be lengthened.

If an attempt were made to telegraph by using only dots, say one dot for a, two dots for b, three dots for c, and so on, we would find that the transmission of a group of words such as "you were very lazy" becomes a somewhat laborious process, involv-

ing the making of 246 dots. By the use of a suitable code, however, comprising combinations of short and long impulses, that is, dots and dashes, the same sentence could be transmitted by 40 key depressions.

In the Morse code, for example, the letters most commonly used are given the shortest combinations, such as dot-dash for "a", dot for "e", and dash for "t", while the longer combinations are reserved for the less frequently used letters such as dash-dot-dot-dot for "b". The spaces between the impulses in a letter are of the same length as a dot mark. The dashes are made three times the length of a dot mark. The space interval between the letters of a word is equal in length to three dot marks, and the space between words themselves, equal to five dot marks. If the frequency of recurrences of the letters in ordinary English is studied, it is found that the average letter combination with its letter space interval is equal in length to eight dot marks or four complete dots, a complete dot being regarded as the mark and the succeeding space of the same length. As the average word in the English language consists of between 5 and 6 letters, it has been accepted in the telegraph art that the length of an average word with its word space interval is equal to twenty-four complete dots. Transmitting at the rate of 100 words per minute using this code would, therefore, be sending the equivalent of 2400 complete dots per minute or 40 per second. Hand sending, however, does not usually exceed 40 words per minute or 16 complete dots per second.

Within the past few years the use of the start-stop printing-telegraph system has been greatly increased. This system makes use of a telegraph code of current combinations different from those of the Morse code, but like them in consisting of short and long current impulses. Being automatic it can be operated at higher speeds than the hand operated system, and usually the speed is set at 60 words per minute which requires that the line shall carry about 24 complete dots per second.

The instrument used to receive signals is a sensitive polarized relay, the armature of which moves between two contact points, the direction of motion being dependent upon the polarity of the current. The transmitting device sends out a current of one polarity for the marks and of the opposite polarity for the spaces. Hence to transmit a dot with its succeeding space there is sent out a current reversal as shown in Figure 1. Such a "square wave" signal is really a combination of a sine wave of fundamental frequency and an infinite

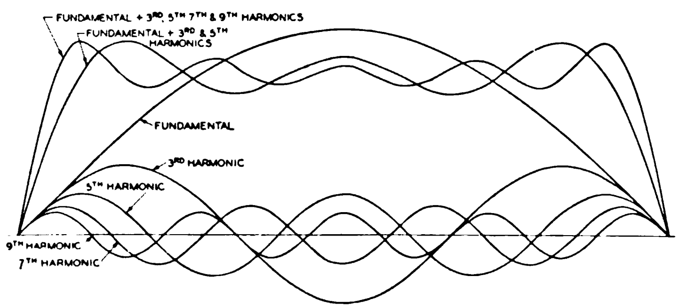


Fig. 2—Harmonics of a fundamental wave tend to square its shape, making it approach more nearly the ideal form given in Figure 1

number of its harmonics. It will be seen from Figure 2 how the addition to its harmonics tends to square up the shape of a sine wave.

If these higher harmonics, however, were to reach the telephone part of a composited circuit they would produce considerable noise, so that means must be provided for shutting them out. This is done by means of coils and condensers of suitable value

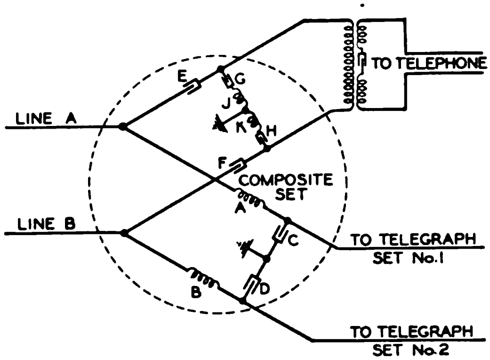


Fig. 3—Separation of telephone and telegraph signals is obtained by the filters, one passing only the low frequencies and the other, only the high

which form a low-pass filter, allowing only frequencies up to about 80 or 100 cycles per second to pass. Further discrimination between the telegraph and telephone currents is obtained by connecting condensers in series with the telephone equipment, which allow the high frequencies of the voice range to pass through but act as a barrier to the low frequencies of the telegraph.

Figure 3 shows in schematic form how this division of the telephone and telegraph current is effected on open-wire composited circuits. Over one pair of wires two separate telegraph circuits and one telephone channel can be provided. If a second pair of wires exists on the same pole line these facilities can be duplicated and in addition a phantom telephone circuit obtained. Since the low-pass filter in the telegraph branch offers little impedance to the passage of frequencies up to about 80 cycles per second, telegraph signals at 24 complete dots per second which are made up of sine waves at 24 cycles per second and their third harmonics (72 cycles per second) can be transmitted. The wave shape is not so good for telegraph purposes as it would be if more harmonics were present to square out the wave form, but on the other hand if the separating point between the telegraph and telephone were moved to a higher frequency the transmitting quality of the telephone channel would suffer.

The compositing set thus serves to separate the telegraph from the telephone message. With the usual connection the subscriber can not tell that the wires over which he is talking are being used also to transmit a telegraph message. Likewise the telegraph message, except for the slight rounding off of the corners of the wave, is unaffected by the arrangement of the circuit to carry telephone conversations as well.

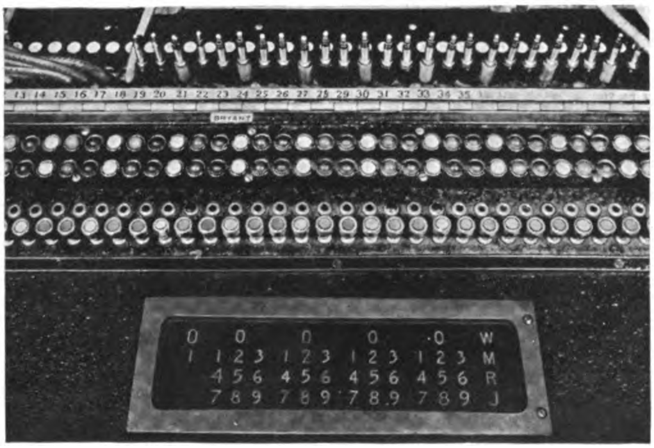
Although it is not generally known to the public, a large part of the entire telegraph traffic handled in this country is passed over leased wires and is not included in the category of public-message business. The American Telephone and Telegraph Company does not handle public-message business but leases wires for telegraph uses; and this leased wire telegraph business of the Bell System is quite extensive as there are nearly a million miles of two-way telegraph channels in operation.

Panel Senders

By W. J. SCULLY
Systems Development Department

SENDERS have been called the brains of the panel system, their action in putting through a call being likened to that of the operator of the manual system. How the sender operates when the subscriber called is also in a dial office has already been described in the RECORD.* Many calls to the central office, however, are for subscribers in a manual office or for special service, and to manage these the sender must employ mental faculties of a higher order such as memory, discrimination, and reason. A brief description of the part the sender plays in the completion of this class of calls will round out the picture.

On a call to a manual telephone the sender registers the dial pulses, a form of mechanical memorizing, consults the decoder for information regarding the route to the desired telephone, and then proceeds to superintend the selection by the district selector — or office selector if used — of a trunk terminating in a manual office before an operator. After the trunk has been found, a lamp, associated with it, lights — indicating to the operator that there is a call waiting on the trunk. The sender now waits for the operator, who signifies that she is ready to complete the call by pressing a trunk-assignment key associated with the lighted lamp. Upon receiving this signal the sender transmits a series of current pulses of differing polarities and strengths which are received and recorded on relays at the manual office. The operation of these relays causes certain lamps to light and display the called subscriber's number, including the party letter, in characters illuminated upon a translucent glass screen set in the keyshelf of the operator's position.



On calls to a manual office the sender causes the desired number, 4259 *in the above illustration, to be displayed in front of the operator*

Handling a call that must be reached through a manually operated tandem switchboard is somewhat similar.

* *"A Mechanical Brain,"* BELL LABORATORIES RECORD, *Vol.* 3, *pp.* 78-81, *November*, 1926.

The sender causes the numerical code of the terminating office to be displayed as well as that of the number called so that the tandem office may know to which office the call is to be routed.

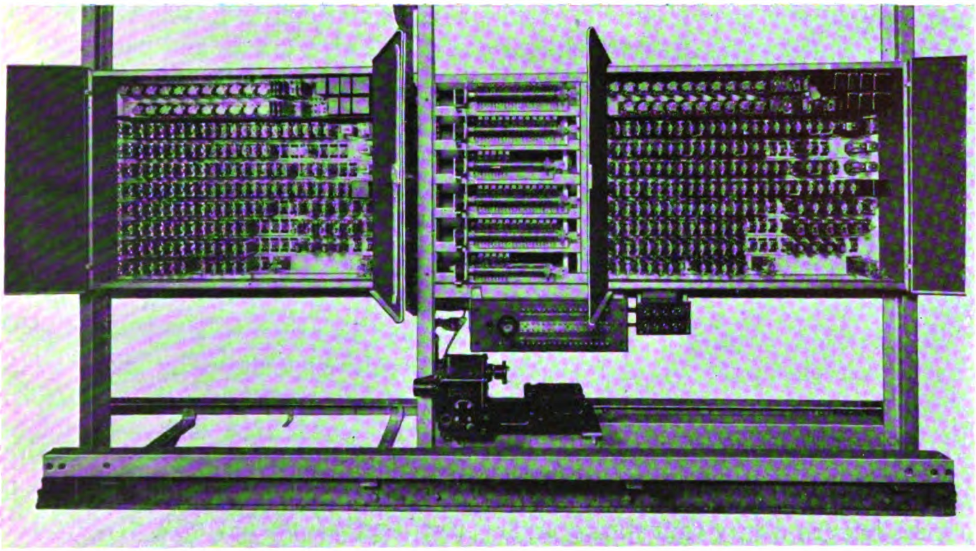
If in the called office there are party lines having letter designations or lines having five digit numbers, the sender is so informed by the decoder which it has consulted regarding the routing of the call. The sender will then wait for approximately four seconds after receiving the dial pulses for the units digit to see whether the calling subscriber wishes to dial a station letter or fifth numerical digit. At the end of that time it assumes that nothing further will be dialed and proceeds with the call. Should a station letter or numerical digit be dialed before the end of the four-second interval the sender immediately continues with the call. If there are no party lines with letter designations or lines having five digit numbers in the called office the sender will be so informed by the decoder and proceed without waiting the four seconds.

When the subscriber desires to reach Long Distance or Information, he dials a special code of three digits such as 211, and the decoder is again consulted regarding the routing of the call. Often it is necessary for the operator to know the class of service of the subscriber's line that is calling, whether for example it is a coin or non-coin subscriber. In such cases the sender passes this information on to the operator by causing the district and office selectors to complete connections from different classes of subscribers to the desired operator over different groups of trunks.

If the subscriber desires to reach the "Special Service" operator he dials "Operator." In this case the sender will if necessary send calls over different groups of trunks to the operator, depending on the class of subscriber calling. On these "Special Service" calls it is desirable that the connection between the subscriber's line and the operator's cord circuit should not have any intervening repeating coils or other apparatus. This is necessary when the call is from a coin subscriber, for example, so that the collection or refund of the coin may be under direct control of the operator. On such calls the sender causes the district selector to connect the tip and ring of the line directly through to the trunk without any bridging apparatus.

A group of senders may serve different classes of subscribers' lines, that is, lines requiring different treatment of their originating calls. For example, coin subscribers must be recognized as a separate class in order to provide for the proper routing of their calls to operators as indicated above and also to insure that a coin has been deposited on a local call before it is allowed to proceed.

The existence of different local dialing areas for different subscribers also requires a distinction to provide for the proper routing of the calls. For instance, one subscriber may have a contract which permits him to dial directly a particular group of local offices while his neighbor is permitted, by the terms of a different contract, to dial directly an additional group of offices. The first of these subscribers, if he should in error dial one of the second group of offices, must be routed to the special operator while the second subscriber dialing the same office must be permitted to go through. For this purpose the sender is required to recognize the class of service of the calling line. This is



Opened doors displaying scores of relays do not reveal the intelligence of the panel sender

accomplished by having each group of subscribers of the same class of service served by its own group of "link" circuits. When a call is made one of these "link" circuits connects to the sender the particular line finder and district selector circuit that is handling the call, and notifies the sender of the class of service of the line which is calling.

The sender passes this information on to the decoder together with the code of the office to which the call is being made. The decoder then decides whether the call should be allowed to proceed to the destination as called for by the office code dialed, or diverted to the "Special Service" operator for final disposition. The sender upon being informed by the decoder of the proper routing for the call proceeds to superintend its completion. This recognition of the class of call by the sender and its correct routing is one of the sender's important functions. An illustration may be cited in the case of a non-coin subscriber calling a number for which this particular subscriber is required to pay an extra charge. The sender with the aid of the decoder will cause the subscriber's line to be connected to the "Special Service" operator who will make the connection for him and also record the necessary information for properly billing the call.

While supervising the work of the selectors in setting up a connection the sender is ever on the alert to detect the presence of irregularities. Should a selector be unable to go ahead with the call because, for instance, all of the trunks in the desired group are busy, it tells the sender this by a reversal of current over the trunk. The sender immediately causes the district selector to send a "busy" tone to the calling subscriber which he recognizes as a request to hang up his receiver for a moment and then try again.

On a call to a dial telephone the sender receives a reversal of current after the called line has been found. It recognizes the reversal, in this instance, as an indication that the call

has progressed satisfactorily, and promptly notifies the district selector to complete the connection. Should this reversal of current be received at an earlier stage of the call, however, the sender would very correctly construe it as an "all trunks busy" signal and act accordingly. The sender in this case might be said to use discrimination.

A situation requiring the use of reason on the part of the sender arises when a subscriber, in moving his telephone about on his desk, inadvertently sets it down with the receiver resting on some books or papers in such a way that the receiver is raised from the hook. In this case the subscriber's line is immediately connected to a sender just as for a regular call, and the sender prepares to record the number desired. Time passes, however, and no dialing occurs. After waiting a reasonable length of time the sender, by the use of reason, correctly comes to the conclusion: "This is not a subscriber desiring a telephone connection otherwise he would make known his wants by dialing." Having made up its mind, the sender causes the subscriber's line to be connected to a trouble-desk where the test man determines the trouble.

It may happen that after the subscriber's line has been "cut through" to the sender and before the subscriber starts to dial, a momentary opening of the circuit occurs due, quite likely, to an accidental jarring of the switchhook. This is called a "preliminary pulse" and is received on the first office-code register. However, the sender knows that the first office-code digit is never 1 and as soon as it is sure that this pulse is not the first of a train of pulses comprising a legitimate digit it prepares a circuit which will absorb the first of the dialed pulses and cause the remaining pulses of the first digit to be received on the first office-code register. This register is thus caused to take a setting corresponding to the first dialed digit. The sender in this case not only recognizes an erroneous condition but proceeds to rectify it at once so that the call may not be delayed in reaching its destination.

Should the subscriber abandon the call at any time after the sender has started but before it has completed its functions the sender notifies the district selector to free the subscriber's line at once so that it will be available for immediate use for another call. In all cases of "abandoned" calls the sender acts to insure the return to normal of the other apparatus used. When necessary it waits a definite time before starting the process of disconnection to permit certain apparatus to return to normal.

Situations occasionally arise, however, where the sender, in spite of its versatility, feels the need of help and it then does not hesitate to call for human aid in the person of a "sender monitor." For example, the subscriber may inadvertently dial only two digits of the three digit office-code followed by the correct number. This constitutes a "partial dialed" condition. The sender knows that the subscriber has not completed his dialing but it is asking a little too much to expect it to correctly guess what the missing digit is. In this case the sender causes a lamp to light before a sender monitor, who plugs in on the circuit and renders such assistance as may be necessary. Also if a coin subscriber fails to deposit the coin or if the call is blocked for any reason whatever for too long a time the sender calls on the monitor for aid.

The Mechanical Delay-Network

By R. L. WEGEL
Research Department

SOMEWHAT reminiscent of the string telephones of our youth is an entertaining offshoot of the Laboratories' research in acoustics, the recently developed mechanical delay-network. Essentially the device is a helical spring, hanging loosely between a transmitting and a receiving element. Wandering through the connecting wire coil, sound vibrations impressed at one end appear at the other some time later.

When recently shown by S. P. Grace to the regional meeting of the American Institute of Electrical Engineers in Atlanta, and to the annual convention of Telephone Pioneers in Boston, the delay-spring was incorporated in a demonstration apparatus. From a microphone transmitter Mr. Grace's voice proceeded to the spring, whose output, translated into electrical vibrations and amplified, was reproduced by a loud-speaker. The audience thus heard the same words twice: directly from Mr. Grace's mouth and one second later from the loud-speaker.

Due to the physical complexity of even their simplest forms, the theoretical explanation of this sort of apparatus is at best difficult. It is not always safe to make simplifying assumptions in discussing these problems; questions of speech transmission especially must be treated in considerable detail, for many of the most curious and important properties of mechanical structures vibrating at voice-frequencies result precisely from this complexity. Fortunately much assistance can be derived from the use of the familiar analogy between electrical and mechanical vibratory systems. Reference to the analogy, even if only qualitative, often makes it possible to predict from telephone experience the nature of the effects which may be expected of the analogous mechanical apparatus.

Treated in this way, the famous problem of beads on a string illustrates well the aspects of vibrating systems which occasion their apparently strange behavior. And, simpler than that of the delay-spring, it is yet sufficiently similar to make possible some significant comparisons between them.

In the idealized form of this classical problem, first discussed by Lagrange and recently interpreted in terms of its electrical counterpart, the string is supposed to have negligible weight and the beads, arranged equidistantly in succession along it, to be infinitesimally small. The resulting model is a series of masses, concentrated at mathematical points, connected by pure weightless elasticity, and vibrating transversely to the direction of the string. Its electrical analog is a low-pass filter, with series inductances corresponding to the masses and shunt capacities to the segments of the connecting elastic string. More generally the mass-points could, of course, vibrate in

three independent directions, the three mutually perpendicular coordinates of space, two of them transverse to the direction of the string and one along it. The corresponding analog is three low-pass filters, through any of which impulses could be independently propagated.

When, however, beads are actually placed on a string, the ideal condition cannot ordinarily be realized sufficiently closely to permit its assumption in simplifying the study of voice transmission over the string. The beads must have length, breadth and thickness, the string must have appreciable weight, and the beads cannot be exactly centered on the string.



Mr. Grace at transmitter end of the network. Spring is shown at "A"

Introducing these complicating realities gradually, it is simplest to consider first real beads on an ideal string: a weightless string, bearing beads possessed of dimensions and mounted off their centers of mass. It is apparent that a force applied through the elastic string to one of the beads at a point not on its center of mass will tend not only to move the bead in the direction of the force but to rotate it as well. The beads may travel in circles or ellipses rather than in a straight line along the direction of the drive. Each bead must, therefore, be considered as an extended body, requiring six coordinates to specify its position or velocity at any particular time: the three coordinates of its center of mass and the three angular rotations about its center of mass. A string has elasticity to twisting as well as to stretching, so that a disturbance of one bead, consisting of rotational as well as back-and-forth motions, will be transmitted in a modified form to the next bead.

Thus there are six ways in which disturbances may be propagated over the string, and, because they are interrelated through the inertia of the mass on account of its off-center mounting these modes of disturbance are mass-coupled. The complete electrical analog comprises six low-pass channels, inductively coupled to a degree dependent on the distance of the bead's mounting point from its center of mass. If the beads were mounted on their centers, the propagation characteristics of each channel would be independent of those of every other. Impulses started over one such channel would proceed without being augmented or diminished by contribution from or to other channels. Practically, however, the mass or "inductive" coupling causes the system to exhibit effects analogous to inductive interference by each channel with every other. This coupling, negligible when the frequency of the vibration to which the system is sub-

jected is low, increases as the frequency becomes higher. Thus, whereas the visible waves of pendulum-frequency, with which classical investigators were concerned, advance intact along loaded strings, waves of voice-frequency are passed about from channel to channel and much modified. These six channels have, furthermore, different velocities of propagation.

If account be now taken of the weight of the string, the six-channel inductively coupled low-pass structure becomes a six-channel inductively coupled multi-band-pass structure. If the elasticity of the string to bending is included in the consideration, the frequency-limits of the passed bands are shifted. Viewed finally in light of the inability to make beads all with exactly the same mass, and to mount them at exactly equal distances from one another and with their points of attachment at the same eccentricities from their centers of mass, each channel exhibits different propagation characteristics in different sections of the string.

In summary, then, the progressive embodiment of our theoretical bead-loaded string into a piece of equipment modifies one after another all its properties. Giving our beads dimensions, we invest them with the three rotatory degrees of freedom, multiplying the system's channels from three to six. Giving weight to our string, we add to the low-pass region of each channel an infinite number of higher pass-bands. Mounting our beads off-center, we couple the channels to one another. Permitting irregularities among the beads and their mountings, we give, to the properties of each channel, variation in differing sections like that of a non-uniform telephone line.

Obviously complication such as this may readily give rise to quite singular phenomena. Methods of actuating the structure can no more be idealized than the structure itself; a real driving mechanism cannot confine its motion rigidly to one dimension, its influence to one channel of the system. The attempt so to confine its action in practice, even when nearly successful, is considerably vitiated of advantage by the parasitic leakages sapping the driven channel through its couplings. When operated, therefore, the system receives initial impulses from the driver in all six channels, which these channels then feed back and forth to one another through their couplings and propagate at their different speeds and in their several ways. When the impulses reach the far end of the string, they have suffered extensive change.

The helical spring, different from the bead-loaded string in effect, is fundamentally similar in principle. It too is a six-channel structure. Its propagation characteristics, however, suit it especially for achieving large delays with compact apparatus.

The steadily increasing importance of mechanical vibrating systems is justifying persistent attention to the theory explaining their properties and to experiments with typical models. The delay-apparatus, interesting in itself, is yet more so as a sprig off the main limb of mechanical vibrators.

Development of the Impedance Bridge

By S. J. ZAMMATARO
Apparatus Development Department

ELECTRICAL measurements were in their infancy when Sir Charles Wheatstone devised a circuit for the comparison of electrical resistances. Figure 1 illustrates the principle on which it is based. A battery is connected across the junc-

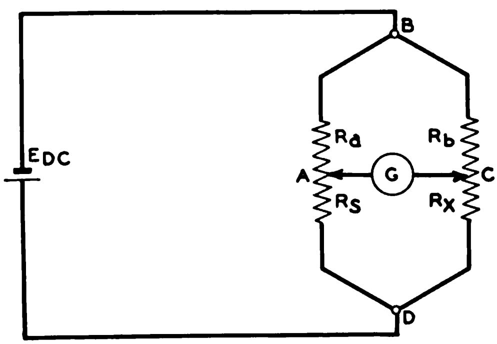


Fig. 1—The principle of a "bridge" illustrated by two parallel circuits with a galvanometer connecting equipotential points

tion points of two parallel resistances and as the total potential drop is the same in each branch, there must be for any point in one branch, a point in the other at the same potential. These equipotential points may be found by connecting one terminal of a galvanometer at any point "A" in branch BAD, and sliding the other terminal along branch BCD until a point is reached ("C") when the galvanometer shows no deflection. These points divide the branch resistances into four components R_a, R_b, R_x and R_s, whose relation, derived from the application of Ohm's law, is $R_x = R_b/R_a \times R_s$.

The more familiar arrangement is shown in Figure 2 where R_a and R_b are fixed resistances and R_x is the unknown resistance to be compared with the standard, R_s. By adjusting the standard zero deflection of the galvanometer is obtained, and the value of the unknown will then be equal to the setting of the standard multiplied by the ratio of the fixed resistances. Establishing the zero deflection may be likened to the process of weighing with a chemical balance in which known weights are added to the standard pan until the pointer registers zero. For this reason Wheatstone called his arrangement a "resistance balance" and the fixed resistances the "arms" of the balance, now more specifically termed "ratio arms." Because the points "A" and "C" are bridged by the detecting device, the detecting branch was known as the "bridge," and this term combined with the inventor's name was used later to designate the whole network.

At the time Wheatstone devised his bridge the only practical sources of electricity were electro-chemical batteries so that the currents were all of the direct or steady type. To the flow of such a current the only impedance offered by a circuit is resistance, a property of the circuit that depends mainly on the material and size of the conductors. As time passed, however, leaving behind a more fully developed telegraph system and the rapidly growing tele-

phone, currents that varied with time became of greater and greater importance. Circuits with a definite resistance measured with a steady current were found to offer much greater resistance to the flow of a varying current. Evidently some quality was present which increased the opposition to the flow of current when the current was constantly changing in value.

It was found that when varying potentials were used, the current that flowed into a circuit depended not only on its resistance but also on other quantities called inductance and capacitance, and the effective combination of these three was called impedance. The values of both reactance and capacitance were found to vary with the rapidity with which the current changed in value or, when alternating current was used, with the frequency.

To measure these new quantities Maxwell, in 1865, introduced the Induction Balance, a form of Wheatstone bridge in which the inductance as well as the resistance of the standard could be adjusted. He used a ballistic galvanometer to detect the transient current caused by the rapid opening of the battery switch. The process of measurement consisted of first balancing for direct-current with the switch closed and a steady

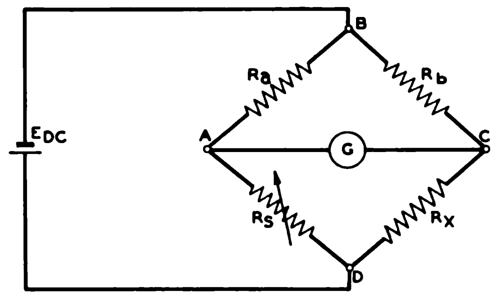


Fig. 2—A more familiar diagram of the bridge bends the parallel circuits into a rhombus with a galvanometer as one of the diagonals

current flowing through the bridge, and of then quickly opening the switch and observing the throw of the ballistic indicator. By readjusting the inductance standard and repeating this process, the ballistic throw could be reduced to zero, when the setting of the inductance standard determined the value of the unknown inductance. The same method could be used for measuring capacitance if a capacitance standard were substituted for the inductance.



Looked at from the operator's position an impedance bridge presents only a collection of dials and terminals

Ayrton and Perry improved the sensitivity of the ballistic induction balance by applying the principle of

the secohmmeter, a commutating device which simultaneously reverses the connections of battery and galvanometer so that twice the deflection will be obtained. This scheme

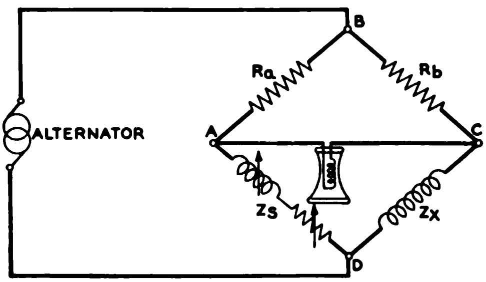


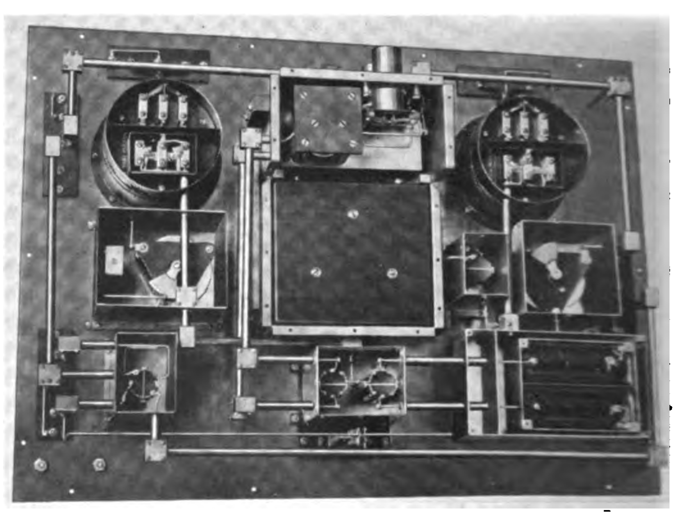
Fig. 3—For measuring impedances a similar bridge may be used but with an alternator replacing the battery and a telephone receiver, the galvanometer

actually amounted to the employment of an impure alternating current in the network and in this light might be considered the forerunner of the modern alternating-current bridge.

Close upon the heels of the Ayrton and Perry arrangement came the use of a small induction coil as the source of current and the replacement by the telephone receiver of Bell, of the ballistic galvanometer which had been employed in the experiments of Lord Rayleigh, Heaviside, Kohlrausch and others. The induction coil, however, gave a current of irregular waveform and indefinite frequency, so that in 1891 Max Wien introduced the use of a small alternator to supply an approximately sinusoidal current of steady frequency.

The evolution of the modern precision impedance bridge is the direct result of the application of minute refinements to the bridge of Wien in order to meet the severe requirements of high-frequency measurements and a general demand for greater precision of results. The open bridge of Wien, shown in Figure 3, and similar types were satisfactorily accurate for the low frequencies used at that time but when it became necessary to measure high frequencies the situation was found to be radically changed.

In an open bridge capacitances exist between each part of the circuit and every other part, also between each part and ground. These are too small to be harmful when the frequency is low but become sources of error as it increases. A bridge of the Wien type, therefore, used with a high-frequency source has an infinite number of stray capacitances, partially indicated by the dotted lines of Figure 4, which become effective and



Viewed from beneath, the shields of an impedance bridge are prominent although in the above view their covers have been removed

cause currents to flow that make it impossible to obtain a correct balance. Another source of error is the capacitance between the bridge and the operator's body, which varies, of course, with every move the operator makes.

In 1904, therefore, Dr. G. A. Campbell devised a shielding scheme whereby the stray currents were not only stabilized but made of definite value so that they could be properly compensated for. Briefly, the arrangement consists of surrounding the individual bridge elements with inner shields connected at one end of the respective elements and with outer floating shields which could be grounded or not, at will. This is commonly known as double-shielding. To isolate the bridge from external

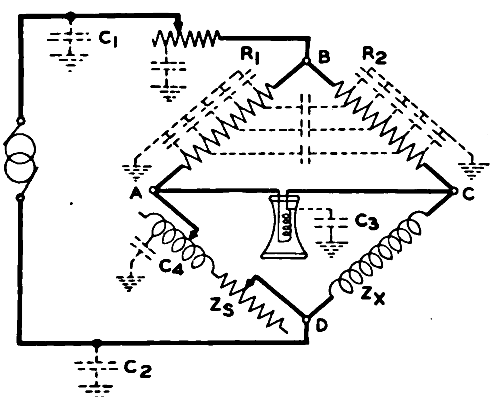


Fig. 4—Used with alternating current an infinite number of stray capacitances exist as indicated above

disturbances, double shielded transformers or repeating coils are inserted between the bridge network and both the generator and the detector, and as a further precaution all the parts enclosed in an overall grounded shield. A schematic of a typical double-shielded bridge is shown in Figure 5. W. J. Shackleton has described such a bridge in some detail and discussed the general principles of bridge shielding in a recently published paper.*

Although the introduction of shielding materially advanced the technique of bridge measurements, there was considerable room left for improving the wave form of the generator supply and for increasing the sensitivity of the detector. Early sources of alternating current, beginning with the first induction coils and running through a diversified array of

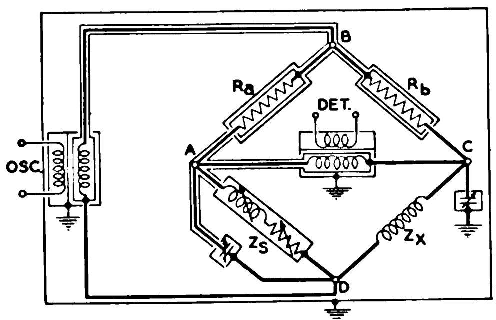


Fig. 5—The shielded bridge controls the stray capacitances so they do not prevent accurate measurement

buzzers, interrupters, microphone hummers, and alternators, all involved some mechanical motion and were consequently limited in both frequency range and purity of wave form. These means were soon supplanted by the Vreeland oscillator, a mercury arc device which, for the first time, employed a purely oscillatory circuit to produce the electrical vibrations. The arrival of the thermionic valve, however, solved both the generator and detector problems to perfection so that even the Vreeland oscillator has almost ceased to be used.

The vacuum-tube oscillator, one of the most familiar pieces of apparatus in our Laboratories, is the best obtainable source of current for

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* *Bell System Technical Journal, Vol. VI, pp. 142-171, January, 1927.*

bridge work. It is capable of furnishing an ample output of alternating current at constant and accurately known frequency, and with a very nearly sinusoidal wave form, throughout a wide range of frequencies. Besides its use as an oscillator the vacuum tube may serve as an amplifier to increase the currents to the detecting receiver, or, when the frequncies are beyond the audible range, as a detector-amplifier of the heterodyne type. By these means the telephone receiver may be employed under conditions that, without the aid of the vacuum tube, would be impossible.

The latest step in the steady advance in bridge measurements is the development of suitable standards of comparison. The resistance, inductance, and capacitance standards used in precision bridges are specially constructed and shielded to secure a maximum stability and flexibility of operation. Their values are determined by a system of calibration based on standards maintained at the Bureau of Standards in Washington. The application of a thorough system of shielding, the use of vacuum-tube oscillators and detectors, and the special construction of accurately calibrated standards are the major contributions that have brought the technique of impedance measurements to its present state of refinements.

Correcting A Mistaken Idea

Although radio has been used for over twenty years for intercommunication, there still remains in the public mind some confusion about the relation of radio and wires. In a recent address on Communications before the Conference of Major Industries, Walter S. Gifford sought to correct the impression that radio and wires, broadly speaking, are competitive. President Gifford regretted that "the public's attention, instead of being directed toward the satisfactory and prompt transmission of communications, has been focused on the means by which such transmission is achieved." He observed that "from its very nature, radio is not and cannot be a substitute for intercommunication by wire. Radio, however, has been and will continue to be of great importance. It has widened the range of communications — and makes possible communication where wires cannot be used, such as with ships and aeroplanes. They (radio and wires) are essentially complementary, and must be so considered if we are to have the best and cheapest intercommunication."

Coil Corrosion

By E. L. FISHER
Apparatus Development Department

In common with most development work the evolution of our electromagnetic apparatus has been attended by numerous associated problems requiring the expenditure of considerable time and effort in their solution. Some of these solutions are yet to be fully attained, the complete answer being progressively realized through increase in the general store of engineering knowledge.

One of the problems besetting the use of electromagnetic apparatus has been corrosion of the wire winding. This trouble appears in operation in the failure of apparatus to function due to the winding having become open-circuited as a result of chemical or electrochemical attack at some point of imperfect protection by the insulating materials.

Failures due to this action, with a few exceptions, are confined to coils wound with enameled wire of 34 gauge or smaller, enamel insulation being particularly liable to corrosive attack because of the presence of occasional minute holes in its surface, at which points corrosive action appears to concentrate.

In the early investigations of coil corrosion it was usually found that this activity became serious only in the presence of a uni-directional potential between two or more windings or between a winding and the iron core. The activity was therefore seen to be mainly electrolytic in character. The electrolyte necessary to the promotion of this action was chiefly moisture from the atmosphere which penetrated the outer insulating materials, taking certain of their impurities into solution.

The severity of the corrosive action being, therefore, controllable to a large extent through improvement in the insulating materials, the history of our wound apparatus design, and especially of relay coils, abounds with records of experimental tests and resultant changes in coil insulation and structure. In fact, in the case of the present-day relay, few of the insulating materials present in the original development of these coils are found.

Improvements have included changes from untreated to impregnated manila papers and thence to varnished and impregnated Kraft papers (high grade chemical wood paper made by the sulphate process); from cotton fibre spoolheads, which contained objectionable chlorides, to phenol fibre; and from coil coverings, containing a starch loading paste which rapidly promoted corrosion in the presence of moisture, to a shellacked serving of dyed cotton thread.

As the corrosive action is electrolytic, a solution of the problem has also been sought by means of a high degree of moisture exclusion from the coil structure. During the early development of the flat type relay, coils were vacuum-impregnated with a special moisture-proofing compound de-

veloped for the purpose. Although this treatment improved the resistance of the coils to corrosion, the comparatively low melting point (140° F) of the wax used became the cause of added difficulties in the field due to leaking of the impregnating compound from the coil onto the operating structure and other apparatus. This led to the discontinuance of the general practice of impregnating and to the re-adoption of a dry coil using improved insulating papers.

As the use of extremely fine gauges of enameled wire became increasingly desirable from a standpoint of electrical efficiency, further improvement in the corrosion-resisting characteristics of wound apparatus was sought. Because the advantages to be realized through the use of finer gauges of wire are especially attractive with relay coils, these again become the subject of experimental investigations intended to improve their moisture-resisting properties.

These investigations have dealt with moisture-proofing attained by surrounding the structure with a surface seal which is highly impervious to moisture rather than by completely impregnating the coil with a high-melting-point moisture-proof compound. Efforts along this line that have shown promise have mainly included tests on the use of a single wrapping of a highly moisture-proofed insulator between the coil winding and the cotton serving.

In actual practice this general type of protection is applied in a somewhat different manner, as illustrated in the covering recently standardized for relay coils. It consists of the replacement of the present covering of shellacked cotton thread by a serving of cellulose acetate silk. This covering is applied directly over the winding in the form of a number of threads, as is usually done with the cotton serving, and a skin is then formed over the entire surface by subjecting the covering to a fine spray of acetone which softens the outer layer and allows it to solidify subsequently into a continuous film that is highly impervious to moisture. This covering also provides a seal at the spoolheads by adhesion to a spoolhead washer composed of a special cellulose cement which is cheaper than the red rope-paper washers as well as an improvement from a corrosion standpoint.

The last mentioned development represents the most efficient means of corrosion prevention now incorporated in the manufacture of our wound apparatus (with the possible exception of the comparatively expensive practice of potting the coils in a metal case) in that it permits, with less corrosion hazard, the use of enameled wire several gauges finer than could be used in older impregnated coils.

A fairly satisfactory solution of the general problem of corrosion of the type of wound apparatus most commonly used in telephone equipment appears to lie, therefore, in the use of surface coverings that are highly impervious to moisture, together with the continued use of properly restricted insulating materials which experience has shown to withstand the test of time.

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As the use of extremely fine gauges of enameled wire became increasingly desirable from a standpoint of electrical efficiency, further improvement in the corrosion-resisting characteristics of wound apparatus was sought. Because the advantages to be realized through the use of finer gauges of wire are especially attractive with relay coils, these again become the subject of experimental investigations intended to improve their moisture-resisting properties.

These investigations have dealt with moisture-proofing attained by surrounding the structure with a surface seal which is highly impervious to moisture rather than by completely impregnating the coil with a high-melting-point moisture-proof compound. Efforts along this line that have shown promise have mainly included tests on the use of a single wrapping of a highly moisture-proofed insulator between the coil winding and the cotton serving.

In actual practice this general type of protection is applied in a somewhat different manner, as illustrated in the covering recently standardized for relay coils. It consists of the replacement of the present covering of shellacked cotton thread by a serving of cellulose acetate silk. This covering is applied directly over the winding in the form of a number of threads, as is usually done with the cotton serving, and a skin is then formed over the entire surface by subjecting the covering to a fine spray of acetone which softens the outer layer and allows it to solidify subsequently into a continuous film that is highly impervious to moisture. This covering also provides a seal at the spoolheads by adhesion to a spoolhead washer composed of a special cellulose cement which is cheaper than the red rope-paper washers as well as an improvement from a corrosion standpoint.

The last mentioned development represents the most efficient means of corrosion prevention now incorporated in the manufacture of our wound apparatus (with the possible exception of the comparatively expensive practice of potting the coils in a metal case) in that it permits, with less corrosion hazard, the use of enameled wire several gauges finer than could be used in older impregnated coils.

A fairly satisfactory solution of the general problem of corrosion of the type of wound apparatus most commonly used in telephone equipment appears to lie, therefore, in the use of surface coverings that are highly impervious to moisture, together with the continued use of properly restricted insulating materials which experience has shown to withstand the test of time.

BELL LABORATORIES CLUB

BLC

ACTIVITIES

OF THE YEAR

1928

Past Presidents

Harry E. Young	Burton W. Kendall
William Wilson	Edward J. Johnson

Club Officers for 1928

Donald A. Quarles	*President*
George F. Fowler	*First Vice-President*
Marie Boman	*Second Vice-President*
David D. Haggerty	*Secretary-Treasurer*

Departmental Representatives

J. C. Kennelty	*Commercial*
A. L. Johnsrud	*Research*
T. J. O'Neil	*Systems Development*
S. J. Stranahan	*Apparatus Development*
G. Rupp	*Plant and Shops*
T. C. Rice	*Patent and Inspection*
P. J. Higgins	*Tube Shop*

Activity Directors

A. F. Gilson	*Bowling*
L. P. Bartheld	*Men's Interests*
Natalie Skinner	*Women's Interests*
C. F. Gittenberger	*Basketball*

Foreword

THE BELL LABORATORIES CLUB was formed about five years ago to organize and coordinate those recreational activities which are of interest to considerable groups of the Laboratories personnel. The Laboratories' only concern in the project was and is to promote the well-being of its members, recognizing as it does that the effectiveness and productivity of the organization as a whole is largely dependent upon the physical health and wholesome mental attitude of the individual contributors to its output. This interest makes it sound policy to encourage recreational activities by providing a permanent staff to administer the numerous details and by relieving the membership of a portion of the expense in the case of those activities which cannot be expected to be entirely self-supporting.

In order to insure the most general use of the facilities offered by the Club our constitution provides that any member of the Laboratories may become a member of the Club simply by indicating his desire to do so. Aside from the permanent Secretary-Treasurer who devotes his time to the affairs of the Club, all the officers and representatives on the executive board are elected by the members they represent. Within the limitations imposed by a budget, which quite naturally must have approval of Laboratories executives in view of its financial assistance, the officers of the Club are free to promote and support those activities that seem likely to be of maximum benefit to the Club members.

While the number of such activities already organized and in successful operation is considerable and the number of members taking part in one or more of them is large, it seems probable that many more might be glad to participate if the nature and scope of the activities were more generally known. With this in mind a report has been prepared showing what the Club has been doing during the past year. This is being sent to all Club members with the thought that they are entitled to full information as to its performance and plans.

The election of Club officers and representatives will be held as usual the latter part of the year. Departmental Representatives on the Club board, acting with the present officers of the Club as a nominating committee, will nominate two candidates for each of the vacancies to be filled. In advance of the election and as a means of informing the electorate there will appear in the December issue of BELL LABORATORIES RECORD a statement descriptive of the candidates, and their qualifications for the offices to which they aspire.

DONALD A. QUARLES,

October 31, 1928. *President, Bell Laboratories Club.*


BELL LABORATORIES CLUB
CHAMPIONSHIP

Recreational Activities For Men and Women

Symphony Orchestra and Glee Club



The Club Symphony Orchestra, conducted by Professor Egon Eibert, opened its fifth season on Thursday evening, October 4. This, the second year of Professor Eibert's direction, finds the Club orchestra proficient in playing quite difficult compositions. At all times, however, new members may be admitted. This season's first rehearsal of the Glee Club took place on Wednesday evening, October 10, under the direction of Professor V. S. Richards.

Both groups are rehearsing weekly (the Glee Club Wednesdays, the Orchestra Thursdays) in the 11th floor Rest Room for twenty-five weeks, in preparation for a joint concert to be held at one of the New York hotels in the spring of 1929.

Bell System Athletic League

In 1926 the first Bell System baseball league, chess league and handball league were organized. To them was added in 1927 a men's basketball league of eight teams. The application of fourteen teams for admission into the baseball league at the start of the 1928 season, and the appearance in the offing of the same number for the basketball league, suggested bringing all intercompany activities for men and women under the supervision of the organization.

At a meeting in May, the Bell System Athletic League of New York was organized, to promote intercompany athletics among the employees of the Bell System in the metropolitan district. D. D. Haggerty of Bell Telephone Laboratories was elected President to serve until June 30, 1929.

Entertainment

Three Club dances spangled the year 1928. The Grand Ballroom of the Hotel Pennsylvania housed the first on February 2. Music was furnished by the Vagabonds, one of the well-known orchestras of the air. At the end of April, the spring dance was held in the Grand Ballroom of the Waldorf. Entertainment by the National Broadcasting Company featured a number of radio stars; Ben



Bernie made the dance music. On Friday evening, November 2, the Club ascended to the McAlpin Roof and danced to Herbert Hood's music.

It has been the policy of the En-

tertainment Committee to hold at least three dances each year; plans have already been completed for a dance atop the McAlpin on Friday evening, February 1, and a concert and dance in the Grand Ballroom of the Hotel Pennsylvania the latter part of April.

Track and Field



On Saturday, May 26, tryouts determined the twenty-seven men and women to represent the Club in the thirteen events of the track and field meet. The meet was held on Saturday afternoon, June 16, at Erasmus Hall Field, Brooklyn; the Laboratories' team won with a total of thirty-two and one-half points.

While the Club has held intramural track meets in the past, this was the first year of competition with other branches of the Bell System in the metropolitan district. The meet was such a success that plans are now being made by the athletic league to promote an indoor meet for men and women in one of the New York armories the latter part of February.

Swimming

For five years Club members have been enabled to secure tickets for the Brighton Beach Baths at one-half the rate regularly charged at the gate; eleven hundred of them were purchased during the 1928 season. These tickets obviate standing in line at the bath houses, and paying double the regular rate during unusually hot weather, similar arrangements have been made for the summer of 1929.

Club members may also purchase at half price from the Secretary tickets for the pool in the Shelton Hotel. Over seven hundred of these tickets have been sold since January; the chilly weeks of winter and spring will see the sale of more.

Hiking Club

The hikers strike out weekly during the eight snow-free months of the year, on an evening, Saturday afternoon, Sunday, or a holiday. A definite schedule of the hikes is printed and distributed twice a year. In addition to walking the scheduled walks, the hikers supped a number of campfire suppers during the past summer.

Photographic Contest

The Club's second annual photographic contest closed with the judging of the pictures by Dr. Zerbe of the Brooklyn Institute of Arts and Sciences on Monday evening, March 12. Prizes were taken by the best three pictures in each of the landscape, still-life and portrait groups. Thirty-nine contestants submitted three hundred prints, some of them very fine indeed. Following the judging, all entries were exhibited in Room 1103.



Plans are now under way for a 1929 contest, to close on January 21. Pictures will be exhibited during an early week of February.

Christmas Poster Contest

Each year the Club holds a Christ-

mas poster contest to secure a poster for exhibition on the Laboratories' bulletin boards during the holiday season. Fifteen posters were submitted in the last contest, all worth the judges' attention and several so good as to make difficult a choice of the ten-dollar prize winner. Each year notification of the contest is given Club members in November; completed posters must be submitted not later than December first.

RECREATIONAL ACTIVITIES FOR MEN

Bowling

The Club Bowling League officially closed its seventh season on April 16 with a banquet at the Hotel Manger, the distribution of prizes by Mr. Craft, and a theater party at the Winter Garden. The two hundred people present were by no means all of those who wished to attend.



During the past eight years, the popularity of bowling has greatly increased. Thirty-two alleys were at the disposal of our bowlers at the opening of the 1928-29 season on Friday evening, September 28. From three groups of forty men each and a fourth group of twenty men, the league has grown to four groups, each with eight five-man teams. In addition to the alleys contracted for the twenty-eight weeks of league bowling, the committee has engaged four alleys for men who wish to bowl regularly but who cannot be accommodated in the league.

The substitute committee is always glad to hear from men who wish to bowl part time in place of absentees.

Basketball



Again, in contest with nine other branches of the Bell System in the metropolitan district, the Club will enter a team in the basketball tournament of the athletic league, to play Monday and Friday evenings in Stuyvesant High School and Wednesday evenings in Erasmus Hall High School from November 12 to January 30. Season tickets admitting their holders to all twenty-seven sessions of the league, and to the dancing which will follow the games, will cost one dollar each. Schedules may be had from the Secretary.

Each year the Club organizes an eight-team interdepartmental basketball league and provides it with gymnasium, equipment, referee and prizes. Its 1928-29 season opened October 30 at Labor Temple, 14th Street and Second Avenue. Two games will be played every Tuesday and Thursday evening from November through February, the first of the pair starting promptly at 5:30.

Chess

Steadily improving its fine record, the Laboratories' team won the championship in the Commercial Chess League of New York for the fifth consecutive year. It goes into action in November against the ten other teams of the Commercial Chess



A sad moment during the golf tournament



Finish of the girls' sixty-yard dash



Talented broad-jumping at the track meet



Finish of one of the dashes

League, in the hope of repeating its victories of previous seasons and obtaining for the second time permanent possession of the trophy, which must be won three years before going out of competition.

In their annual telegraphic chess match, the Laboratories' team was defeated by the Hawthorne Chess Club for the second time in ten years. It won, however, the first of the annually-planned telegraphic chess matches with the Bell Telephone Company of Canada's Montreal office. In addition to these outside activities, the chess players hold each year a tournament among themselves, dividing into two classes for weekly matches.

Golf



Indoor golf, at at the Vander-Built-In course, has become one of the most popular Club activities; seventy-five players took part in the tournament in January and eighty-three in March. Each man played thirty-six holes in the qualifying round and the sixty-four who qualified were divided for the finals into two groups of four classes each. More indoor contests have been scheduled for December 5, January 30 and March 27.

Spring and fall brought golfers outdoors for two tournaments at the Salisbury Country Club, Salisbury Plains, Long Island. In June, eighty men went the qualifying round of eighteen holes of handicap medal play; in September forty-seven men, a record fall turnout, handicapped from scores made in previous tournaments and divided into three groups with the same prizes for each, completed a tournament in one day. Course number five at Salisbury will be the scene of two Club tournaments in 1929, on June 1 and 8, and September 21 and 28.

Tennis



This fall the Club's first tennis tournament attracted to the Mammoth Courts in Brooklyn, forty aspirants to doubles honors. Singles and doubles championship tournaments have been planned for 1929.

Bridge

The men's bridge club plays two ten-week tournaments annually; the first for this season started October 8 and is meeting on Monday evenings at six o'clock. Each player pays a weekly fee of fifty cents, and the



Club donates the prizes. In this year's year's edition of the annual tournament at 195 Broadway with the men's bridge club of the Western Electric Company, forty men from each organization took part. The 1929 match will be played the latter part of January.

Four or five mixed bridge parties with the women's bridge club take place each season.

Handball

From the twenty-four men who

took part in the second annual Club handball tournament at Labor Temple, a team for the Bell System matches tournament was picked. This tournament, staged during April in the gymnasium of the Western Electric Company's Hudson Street building, was won by the American Telephone and Telegraph Company team. Again in 1929 the Club handball tournament, in Labor Temple on Tuesday and Thursday evenings during March, will be followed by the Bell System tournament early in April.

BASEBALL

The Bell System Baseball League of New York opened its 1928 season on April 30 at Erasmus Hall Athletic Field. In order to provide a sufficient number of playing days for the fourteen teams, it was necessary to organize them into two leagues and hold a post-season series between the winners. The large number of spectators attending most of the games found them well worth seeing, for competition was exceptionally keen,

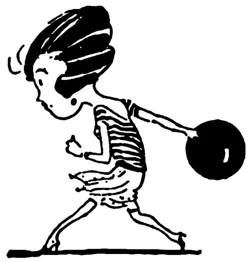


and the teams were close rivals to the last. The season closed with a banquet, and the distribution of the player prizes and the trophy, on September 20.

Teams representing the eight major groups of the Laboratories composed the Club interdepartmental baseball league for 1928, playing at Erasmus Field from May 5 to July 31. To Mr. Dixon, representing the unbeaten Systems Development Department team, the Spalding championship trophy was presented, and he in turn distributed the individual prizes. Option for the rental of Erasmus Field assures it for 1929.

RECREATIONAL ACTIVITIES FOR WOMEN

BOWLING



Bowling for women, a new activity, attracted fifty-three to the elimination contest in February. From them twenty women were picked; they played, as four teams, every Friday evening until April 13. Contract with Dwyers Bowling Alleys reserves four alleys for our women each Friday evening from October 19 to April 12.

GOLF

Indoor golf for women is another new activity of the Club. Twenty-eight women took part in the first tournament, at the Vander-Built-In golf course in March. Two similar tournaments will be held during the coming winter.

BRIDGE

For ten weeks the women of the bridge club meet every Tuesday evening to compete in their midwinter tournament for prizes donated by the



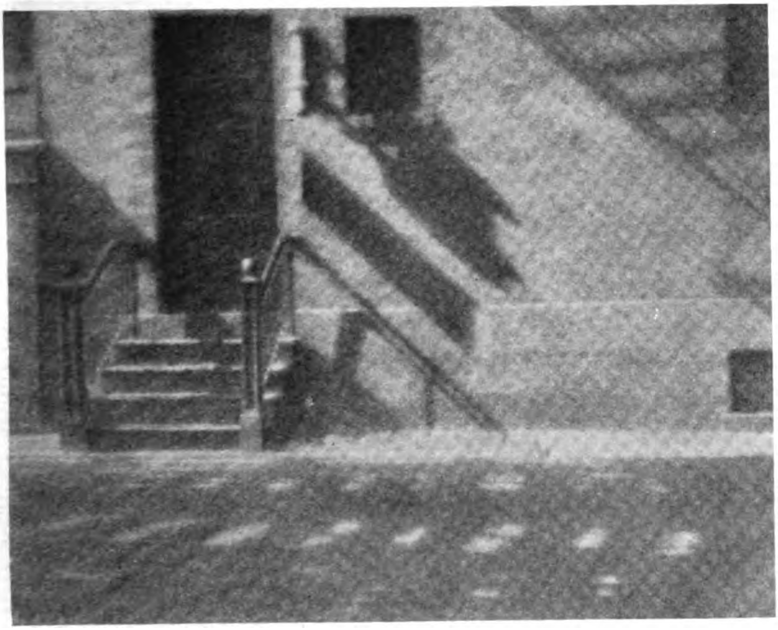
Girls' basketball team, 1927-28



At one of the baseball games



The Laboratories' chess team



A prize-winning photograph



The 1927 prize Christmas poster

Club. In February the women from West Street won the first annual bridge tournament with the women from the Western Electric Company at 195 Broadway, twenty from each company contesting. Since October 5, the bridge enthusiasts have been playing in this season's tournament for the weekly and season prizes.

Physical Training for Women

The physical training course for women consists of ten lessons in athletic dancing; two such courses are held each year. The classes for the fall and winter season started on Friday evening, October 19, again under the direction of Professor Louis Vecchio.

Swimming

During 1928 the Carroll Club swimming classes were more popular than ever before in their three-year history. The mid-winter classes, held two evenings a week for three months, were followed at once by two new classes, and these in turn by a third session of two classes, each



meeting once a week. The three sessions, a record number for six months, accommodated one hundred and seven women. The fourth class of the year began on September 17, and it will meet during ten weeks on Monday and Wednesday evenings.

A definite program, bringing before the women of the Club the importance of knowing how to swim, should spur those who have not signed up with the previous classes to attend the fall, winter or spring session of 1928-29. The fee for a course of eight lessons is two dollars and fifty cents. Miss Kathryn Spranger of the Carroll Club staff is the swimming instructor in charge.

Basketball



During November and December of 1927 the Club offered the women of the building eight weeks of training in the fundamental principles of basketball. During the three following months two basketball teams represented the Club in ten games, seven of which they won, with the women from commercial houses and clubs. A game with the Hempstead High School team in the armory at Hempstead closed the season.

A similar program for 1928-29 began with four weeks of professional instruction, and will continue with a series of outside games, including those of the Bell System basketball League. A contract with St. Luke's church permits the Club to use St. Luke's gymnasium for women's basketball until early in March. The games will precede those of the men's league on Wednesday evenings in Erasmus Hall School.

D. D. Haggerty,
Secretary and Treasurer.

October 31, 1928.

Activity Directors, Managers, and Committee Chairmen for Fall and Winter Season

Bowling, men	*A. F. Gilson*
Basketball, men	*C. F. Gittenberger*
Golf, men	*F. J. Canavan*
Orchestra	*D. D. Miller*
Dances and Entertainments	*D. R. McCormack*
Chess	*E. G. Andrews*
Track and Field	*L. P. Bartheld*
Photographic Work	*Miss M. Horne, K. B. Lambert*
Hiking	*Miss P. Barton, A. Grendon*
Handball	*L. P. Bartheld*
Bowling, women	*Miss M. F. Kane*
Basketball, women	*Miss M. Boman*
Glee Club	*Miss Van Riper, P. H. Betts*
Bridge, men	*G. T. Lewis*
Bridge, women	*Miss K. Munn*
Tennis, men	*W. Kuhn*
Golf, women	*Miss N. Skinner*
Bell System Athletic League Representative	*D. D. Haggerty*
Committee Representing Men's Activities	*L. P. Bartheld*
Committee Representing Women's Activities	*Miss N. Skinner*
Swimming Classes for Women	*Miss F. Steel*
Dancing Classes for Women	*Miss Boman*
Elections Committee	*D. A. Quarles*
Special Cut Rate Privileges	*D. D. Haggerty*
Publicity	*D. D. Haggerty*

Trunk Hunting Switches

By R. L. QUASS
Systems Development Department

THERE is a very definite trend in America today towards the introduction of labor-saving machines in every line of endeavor and their use, probably more than any other thing, is responsible for our present state of prosperity. This trend is especially noticeable in our own business, where a large number of dial system offices have already been cut into service and where automatic devices are being applied more and more to replace hand operations in the manual telephone systems, both to increase their efficiency and shorten the time for making connections.

One of the more recent applications of automatic devices to the manual telephone plant is illustrated by trunk-hunting switch equipment recently installed for the Pacific Telephone and Telegraph Company at San Francisco and Oakland, California. A map of this area, shown in the accompanying illustration, gives an idea of the economic problems sometimes encountered due to geographical location in providing adequate trunking facilities. Each circle on this map represents a telephone building in which is located from one to six central-office units. Subscribers of each office must of course be able to call subscribers of any other office, thus necessitating a tie cable between San Francisco and Oakland which is nearly eight miles long, five miles of it under the bay.

Formerly this cable was made up of many separate groups of trunks to provide enough talking paths for each office on one side of the bay to reach each office on the opposite side. The number of such paths was ample to carry the inter-office traffic then existing but the number of calls so increased that additional facilities were imperative. The program adopted by the Pacific Telephone and Telegraph Company to care for this expansion and provide for future growth contains two interesting fea-

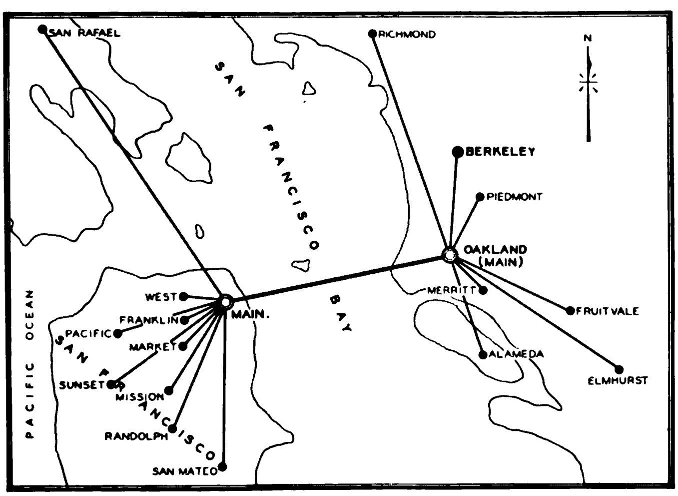


Fig. 1—Trunk hunting switches are made particularly desirable because of the long cable under San Francisco Bay

tures — first the changing over of the trunking from a call wire to a straightforward trunking basis, and second the introduction of trunk-hunting switch equipment, sometimes called trunk-grouping selectors.

Straightforward trunking enables the "A" operator herself to select the first idle trunk to a "B" operator in the distant office in which the called party is located, whereas on a call-wire basis it is first necessary for her to depress a call-circuit button on a separate circuit leading to the distant operator's telephone set and obtain by assignment the number of the idle trunk to be used. Straightforward trunking provides greater accuracy, simplifies the training of operators, and increases appreciably the overall operating efficiency of the switchboard.

The introduction of trunk-hunting switches is particularly interesting because it marks another use for automatic equipment in manual systems. Two methods of reducing the number of pairs in the cable between San

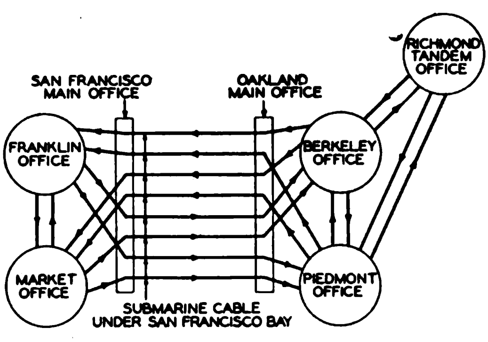


Fig. 2—Formerly each office had its own trunks to every other office

Francisco and Oakland were possible. A tandem board could have been installed or trunk-hunting switches used at each end of the cable. Due largely to the concentration of traffic over a definite channel the trunk-hunting equipment proved the more desirable. The switches are not only cheaper but involve fewer operating errors and give quicker service than a tandem board although the latter would save a few more cable pairs.

The saving in cable pairs, which more than pays for the cost of the

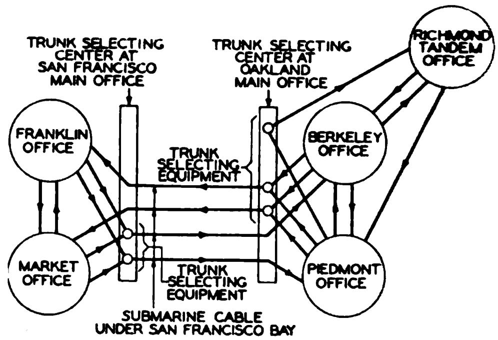


Fig. 3—With trunk-hunting switches the total number of trunks may be reduced because of the arrangement of the trunks in common groups

switches, results from combining small separate groups of trunks into a larger common group. This may be illustrated by referring to Figure 2, which shows the old method of connecting two of the twenty-four San Francisco offices by direct trunks to two of the nineteen Oakland offices, each line in this figure as well as Figure 3 representing a group of one-way trunks. If mechanical means can be introduced at the San Francisco Main Office that will direct a call from the Franklin or Market Office as well as other offices in San Francisco to the Berkeley Office in Oakland over the first idle trunk of a common group of trunks, then all the economies of combining trunk groups can be obtained as indicated in Figure 3. The small circles shown in Figure 3 indicate the presence of trunk-hunting equipment with a corresponding reduction in the number of trunks required between Oakland and San Francisco.

There are twenty-four offices in San Francisco that must be connected with any one of nineteen offices in Oakland and similarly the Oakland Offices must be connected with any one of the San Francisco Offices. If direct trunks without trunk-hunting equipment were used, approximately 156% more trunks would be required under San Francisco Bay.

The trunk-hunting switch circuit introduced on each trunk from "A" boards, as indicated in Figure 3, consists of a 200-type rotary selector switch with an associated circuit of four relays, shown in Figure 4. The rotation of the switch is started from its preceding position by the operation of the line relay. The switch is made busy to calls from other operators by the holding relay which also controls the disconnect. The trunk-hunting relay is used to provide more positive control of the switch while the cut-through relay is used to connect the talking circuit to the idle trunk after it is found. A circuit containing a supervisory and sleeve relay is also required in each common trunk leading from the switch bank to the distant office.

When the "A" operator plugs into a Berkeley trunk at Market Office, for instance, the switch of the corresponding trunk in Main Office is caused to step to the first idle trunk to Berkeley and the trunk made to test busy to all other calls for Berkeley. The corresponding trunk lamp at this office lights and an idle "B" operator is automatically connected to the trunk. This operator learns the number of the party wanted and places the plug associated with the trunk into the jack of the called line.

Trunk-hunting equipment of this character will probably find application in many multi-office areas having manual-office units. One of the uses, for instance, is in connection with trunks to outlying points as illustrated by the Richmond Office, Oakland, which is located at the most northerly edge of the Oakland area. Here it has been found economical to install switching equipment at the Main Office, in the trunks to the Richmond Office from a number of offices lo-

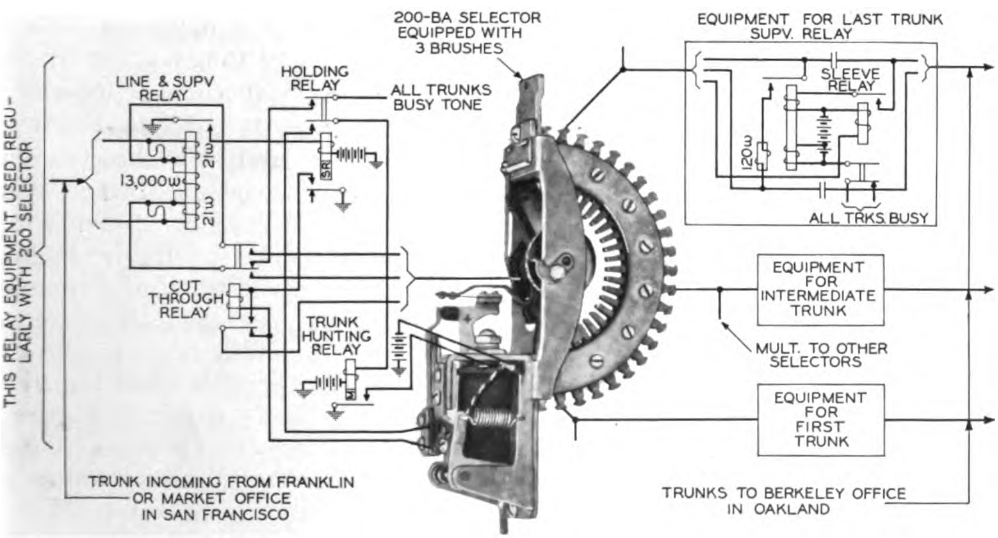


Fig. 4—The general appearance of the trunk hunting switch and some typical associated circuits are shown above

cated near the switching center, as shown in Figure 2 where the Piedmont Office is representative of one of the nearby offices. A similar situation exists in San Francisco where switching equipment is being introduced on trunks to the more distant offices of San Mateo and San Rafael.

Although trunk-hunting switches do not find general application in closely knit multi-office areas where it is impractical to carry all trunks through a trunking center, they do find application in these areas for specific purposes and are destined to play a considerable part in increasing the speed and efficiency of manual telephone systems.

New Laboratory for Sound-Film Development

Construction is soon to start on the first experimental laboratory to be built expressly for the study of problems relating to sound films. This building — of three stories — is to be erected by the Laboratories on a plot 50 by 118 feet at 151 Bank Street, in the block it now occupies. While facilities will be provided for the complete production of sound films, their use will be restricted to experimental work and no commercial production will be undertaken.

The top floor of the new building will contain a studio 67 by 45 feet, provided with adjustable acoustic treatment to control the reflection of sound from walls and ceilings. Acoustics of the adjoining monitoring room will simulate those of an acceptable theatre, so that sounds heard from the monitoring loud speaker during recording will be closely similar to those which will later be projected in theatres. Offices and dressing rooms, and laboratories for both film and disc recording will occupy the second floor. On the ground floor will be a projection room for the showing of sound-pictures, and a plant of advanced design for handling film. Air for the entire building will be cleaned and conditioned. Sprinkler protection will be provided in accordance with the most advanced principles of fire protection engineering.

Locating Faults on Toll Lines

By A. J. PASCARELLA
Systems Development Department

SERVICE over long toll lines is remarkably continuous when the almost countless things are considered that can happen to lines running over all sorts of country and subject to all possible conditions of weather. Even cables, which to a great extent are taking the place of the more vulnerable open wires, are subject to damage due to various things which sometimes create faults in conductors. Even when the damage to the sheath is not so extreme, moisture may leak in and spoil the insulation. Toll test-boards, therefore, to analyze and locate the faults which occasionally occur are always necessary and have attained a high degree of convenience and accuracy.

The type of a fault may be indicated to some extent by its effect on transmission. Grounds or foreign potentials are usually accompanied by noise; crosses or short-circuits, by no transmission and absence of noise; and opens, by noise and poor transmission. This audible evidence, however, is used only as a preliminary indication. Final testing is by a voltmeter or Wheatstone bridge. These are wired to keys, cords, or jacks and other apparatus to form convenient test circuits. The voltmeter is used for determining the type of fault, and the Wheatstone bridge for its location.

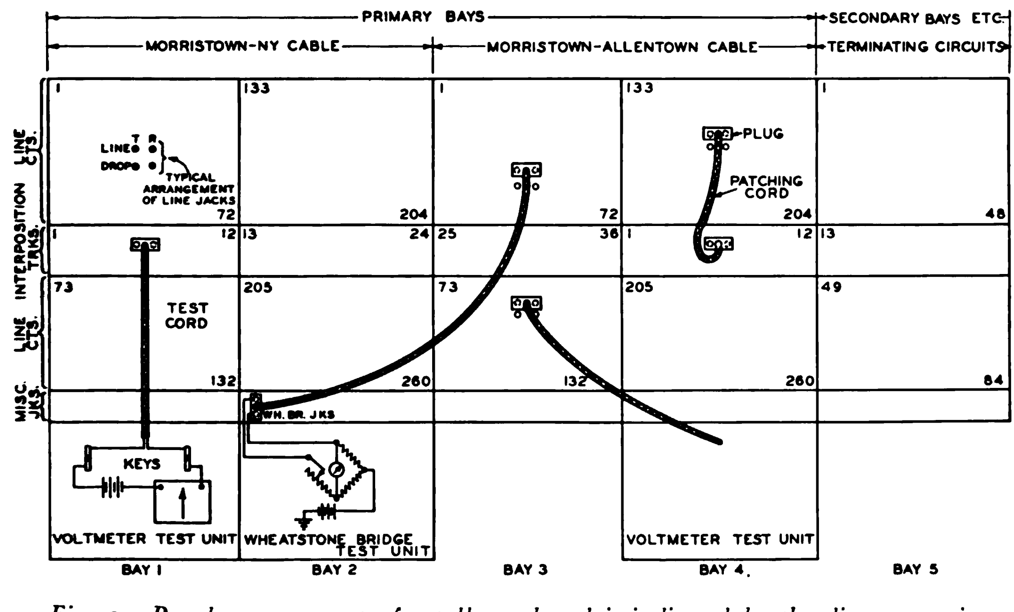


Fig. 1—Panel arrangement of a toll test board is indicated by the diagrammatic sketch above

A toll testboard, shown in Figure 1, consists essentially of a jack panel through which connections are made to the toll lines, and a unit in which is mounted the test circuit apparatus. Jack-ended trunks, extending among different positions of the board, also appear in the jack panel, and by means of them, toll lines terminating in one position may be extended to a different position when occasion demands. The flexibility of this arrangement makes all lines accessible at any position and enables several test men at the same time to test lines terminating at one position.

Jacks connected to the toll lines are of the series type in which the circuit passes through a contact normally closed. Inserting a plug opens this contact and disconnects the apparatus on one side of the jack. Testing circuits are cord-and-plug-ended on some types of boards so that only the insertion of the test plug into the line jack is required. In other types of boards the test circuits terminate in jacks, making separate patching cords necessary to connect them to the toll lines.

The test board enables an attendant not only to test either the toll lines or the equipment in the office, but to "patch" equipment to the toll line; that is, to change, add, or subtract line equipment. Patching makes possible the rapid replacement of defective terminal equipment or defective line wires in cases of emergency. Patching also becomes necessary when a severe storm affects, for example, only the cables or lines going in one direction. Under these conditions the voltmeter position associated with the bay containing the jacks of these lines would be insufficient to take care immediately of all the faults which might develop. Another attendant by means of patching cords or interposition trunks would patch, as shown in Figure 1, some of the defective lines to another voltmeter position where he would make the preliminary tests to help out.

If a toll line becomes faulty so that it is necessary to route calls over another line, the test man transfers all the circuit facilities by patching the terminal equipment, including telegraph apparatus, from the faulty pair to the new circuit. This is easily accomplished by connecting into the jacks as shown in Figure 2.

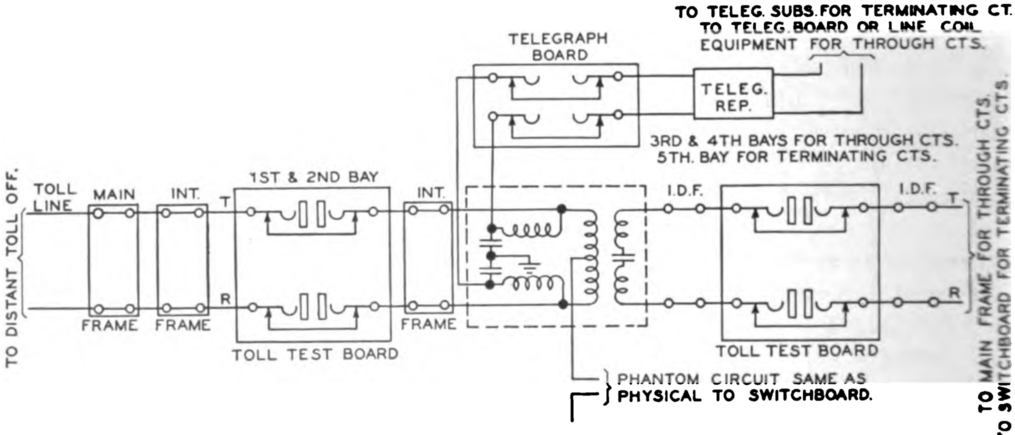
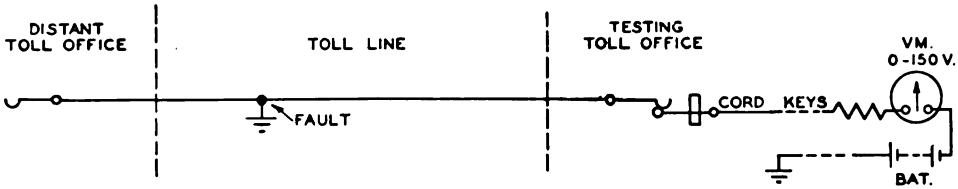


Fig. 2—Jacks on the panels are connected to the toll lines and equipment so that preparation for testing or rearranging equipment is merely a matter of inserting plugs

Test men, not only in the same office but in distant offices, cooperate in determining faults. When these occur, the test man at one station first establishes a connection with a test man at the distant station over another circuit and then attempts to carry on a conversation with him over the faulty pair. Following this the faulty pair is tested with the voltmeter to determine whether the fault is a short, open, or ground. After determining the nature of the fault, the test man uses a Wheatstone bridge to locate it. This measurement is also made by the test man at the distant station and the two results are compared for the final location.



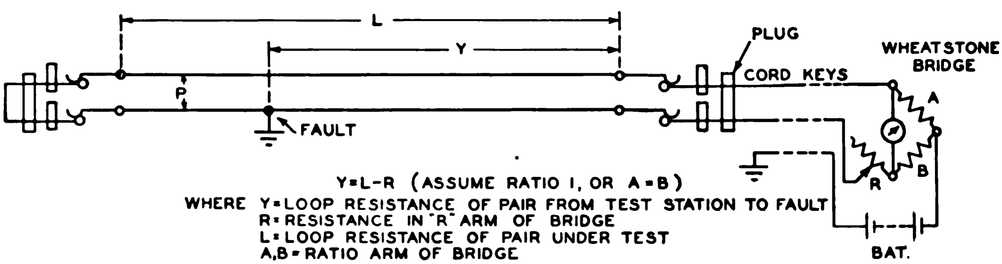


Fig. 3 (above)—Identification of a ground is obtained from a voltmeter plugged into the circuit as shown

Fig. 4 (below)—To determine the location of a ground requires the use of the bridge

Let us assume that the circuit is grounded as shown in Figure 3. The test cord is connected to the line jack and by means of keys the voltmeter and battery are connected in series with the ground and the faulty wire. A deflection of the voltmeter needle will show that the line is grounded. The grounded line is connected to the other wire of the pair by the test man at the distant station and then the circuit is connected to the Wheatstone bridge as shown in Figure 4. The pair of wires is thus connected in a bridge circuit with the battery current transmitted to the distant fault through the ground. When the bridge is balanced, the resistance marked "R" is equal to the loop resistance from the distant station to the fault. This resistance measurement can easily be expressed in terms of wire length to determine the location of the fault.

If two wires are short-circuited, the voltmeter will again be used to determine the type of fault and the Wheatstone bridge, the location. A diagram for this condition is shown in Figure 5. Instead of using the earth to conduct current to the fault the test man employs one of the two wires which are short-circuited or crossed. A deflection on the voltmeter will indicate a short or a cross, and the resistance of the variable arm of the Wheatstone bridge will again be equal to the loop resistance from distant station to the fault.

If the line is open, the voltmeter needle will be deflected only momentarily on test and the Wheatstone bridge will be used to determine the location of the fault with the circuit which take into account the physical characteristics of the conductors as well as temperature, loading, and other factors. The results determined by calculation are usually modified

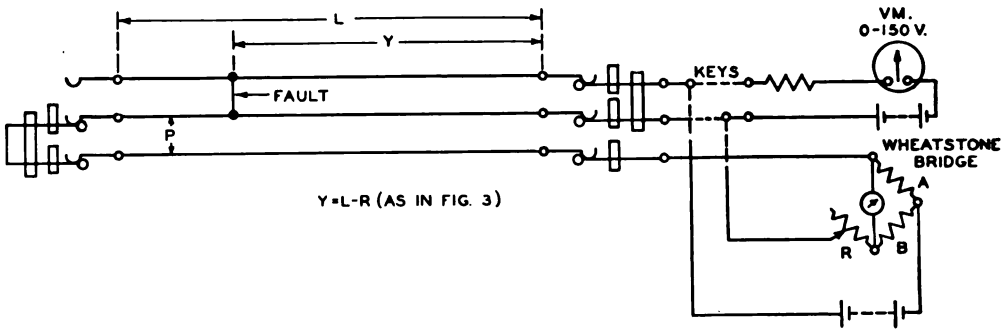
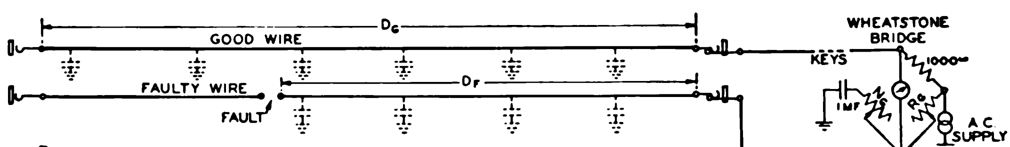


Fig. 5—The location of a short-circuit requires the use of a third wire usually selected from a good pair of the same cable

shown in Figure 6. The location test for an open circuit is primarily a method of comparing the capacity of a bad wire to that of a good wire. The Wheatstone bridge is arranged in the form of an impedance bridge to which is applied four-cycle alternating voltage. Two balances are obtained, one with the faulty wire connected to the bridge and one with a similar good wire connected to the bridge. A comparison of the readings of the "R" arm of the bridge indicates the distance to the fault.

The actual location of faults is determined by the use of formulae by the test man in accordance with his experience. Information as to the location of the fault is transmitted by the test board man to a lineman who proceeds to clear the trouble. It will be seen that accuracy in locating the fault is of great importance as it determines the out-of-service time as well as the expense of clearing the trouble. By proper use of the high-efficiency testing equipment now available it is possible under average conditions to locate faults with reasonable accuracy. The toll test man is thereby able to contribute a vital part to the quality of Bell System service.



$D_F = \frac{R_F}{R_G} D_G$ WHERE D_F = DISTANCE TO FAULT FROM TESTING STATION.
D_G = DISTANCE BETWEEN STATIONS.
R_G = RESISTANCE IN VARIABLE ARM OF BRIDGE TO BALANCE GOOD LINE BETWEEN STATIONS.
R_F = RESISTANCE IN ARM OF BRIDGE TO BALANCE FAULTY LINE.
N_G, N_F = RESISTANCE IN ARM OF BRIDGE TO BALANCE OUT RESISTANCE COMPONENT OF LINE.

Fig. 6—To locate an open, a bridge reading is taken on each wire of the defective pair

News Notes

Dr. Jewett is chairman of the committee organized by the National Research Council to plan the theme and program for the scientific aspects of the Chicago World's Fair Centennial Celebration in 1933.

Members of the British Post Office Telegraph Committee who have been visiting the United States were entertained by Dr. Jewett at dinner at the University Club on October 20. His guests included Colonel A. G. Lee, and Messrs. L. Simon, G. T. Archibald, J. Stuart Jones and A. E. Stone. Others present were Messrs. O. B. Blackwell, M. B. French, R. W. King, T. G. Miller, L. F. Morehouse, P. Norton, H. S. Osborne, J. J. Pilliod, J. L. R. Van Meter and W. Wilson.

On November 9, Dr. Jewett visited Toronto to consult with Hon. Howard Ferguson, Prime Minister of Ontario; Hon. W. Finlayson, Minister of Lands and Forests; and Sir Joseph Flavelle, on the subject of the new Ontario Research Foundation. Sir Joseph, Chairman of the Foundation, entertained a number of the conferees at a luncheon at the York Club.

P. Norton, in addition to his present duties as Assistant to President Jewett, has been appointed Editor of the Bell System Technical Journal.

At the Michelson meeting of the Optical Society of America, held in Washington November 1 to 3, H. E. Ives presented to the society the Frederick Ives Medal. Endowed by H. E. Ives in honor of his father, a pioneer in applied optics, the medal is to be awarded by the society biennially "for distinguished work in optics." This is the disposition he has chosen for the premium which accompanied the John Scott Medal awarded to him by the City Trusts of Philadelphia in 1927 in recognition of the development of television in these Laboratories. Papers read at various sessions of the meeting included "A Camera for Making Parallax Panoramagrams" by Mr. Ives, "Optical Conditions for Direct Scanning in Television" by Frank Gray and Mr. Ives, and "The Scattering of Electrons by Crystals" by C. J. Davisson. In charge of W. A. Marrison were exhibits of the continuous film oscillograph and the polar oscillograph, instruments for recording periodic phenomena of long and short duration respectively.

At the November 5 meeting of the Colloquium, C. J. Davisson, the retiring president, spoke on "Scattering of Electrons by Crystals." R. M. Burns addressed the Colloquium on November 19 on "Recent Developments in Electroplating."

Apparatus Development

F. F. Lucas addressed the members of the Brooklyn Institute of Arts and Sciences on November 1, on "The Ultra-Violet Microscope."

V. M. Cousins spent several days at Hawthorne testing amplifiers for talking movies.

O. L. Walter visited Hawthorne in connection with manufacture of the 202-A phonograph reproducer set.

C. F. Boeck and J. D. Sarros attended the Southern District Conven-

tion of the A. I. E. E. at Atlanta.

O. F. FORSBERG visited Hawthorne during the week of October 29 for conferences on dial system apparatus.

F. H. HEWITT was at Hawthorne during the week of November 5 in connection with the manufacture of the new decoder relays. He also inspected step-by-step equipment at Champaign, Illinois.

J. ABBOTT attended a conference at the Philadelphia Instrument Shop on changes in the Type 5 dial tester.

THE FIRST WESTERN ELECTRIC fifty-kilowatt broadcasting transmitter to go on the air is that of the Crosley Radio Corporation at Mason, Ohio. Its initial program was radiated at 9 P. M. on October 20. The equipment, which is a counterpart of that in our laboratory at Whippany, was installed under the supervision of H. S. Price, W. J. Adams, J. W. Smith and R. E. Poole. E. L. Nelson was present at the opening ceremonies.

RESEARCH

G. W. ELMEN lectured before the Franklin Institute in Philadelphia on November 8 on the subject "Magnetic Alloys of Iron, Nickel and Cobalt." For the benefit of members of the Laboratories, Mr. Elmen delivered the same lecture in the Auditorium on the previous evening.

K. K. DARROW addressed the New York Section of the A.I.E.E. on "Crystals and Waves."

J. R. HEFELE spoke on television before the Alpha Chapter of Omega Delta Phi at Cooper Union.

H. A. FREDERICK AND H. A. LARLEE attended a general conference on telephone instrument matters at Hawthorne. Mr. Larlee subsequently made a study of the latest developments of the handset.

W. E. ORVIS was engaged in the study of carbon manufacture at Hawthorne from October 21 to 26.

R. M. BURNS AND L. H. CAMPBELL visited the Bureau of Standards at Washington in connection with soil corrosion studies and paint investigations. They later visited the Research Laboratory of the New Jersey Zinc Company at Palmerton, Pennsylvania, for the same purpose.

R. R. WILLIAMS conferred on general engineering problems connected with the work of the chemical laboratories at Hawthorne.

H. FLETCHER AND L. J. SIVIAN viewed the Optical Exhibition held at Washington, during the Michelson Meeting, under the joint auspices of the Bureau of Standards and the Optical Society of America.

V. E. LEGG attended the November 8 meeting of the Franklin Institute in Philadelphia.

O. E. BUCKLEY addressed the Physics Seminary of Cornell on October 22 on "Researches in Ferromagnetism."

K. K. DARROW spoke on "New Knowledge Concerning the Scattering of Light" before Pi Mu Epsilon at Washington University, St. Louis.

L. J. COBB visited Hawthorne in connection with transmitter testing machines.

PATENT

I. MACDONALD, T. P. NEVILLE, J. W. SCHMIED AND P. C. SMITH visited Washington in connection with the prosecution of applications for patent. G. M. CAMPBELL visited Ottawa, and G. H. HEYDT, Montreal, for the same purpose. G. C. LORD visited Mattawan, New Jersey, and I. MACDONALD went to Philadelphia on patent matters.

CORDELIA MATTICE, an attorney of the Patent Department, was ad-

mitted to the Bar of New York State.

Systems Development

E. Vroom spent several days in Pittsburgh investigating relays for echo suppressor equipment.

R. A. Leconte inspected the new repeater stations on the Washington-Atlanta cable at Durham and Greensboro, North Carolina.

H. R. Vail spent a week at Hawthorne making tests on carrier telegraph equipment.

F. S. Entz investigated pilot wire regulators for telephone repeaters in Philadelphia.

R. S. Wilbur, E. D. Johnson and D. C. Meyer visited the repeater station at Allentown, Pennsylvania, to consider improvements in pilot wire regulating equipment.

H. T. Langabeer visited Hawthorne to discuss power plant problems.

D. H. Wetherell discussed dial equipment problems with members of the staff at Hawthorne.

V. T. Callahan has returned from Oklahoma City where the first 150 horsepower Type ATT gas engine was placed in operation.

W. W. Brown conferred with engineers of the Ohio Bell Telephone Company on problems incident to introduction of dial apparatus in Cincinnati.

R. E. Noble visited the new step-by-step dial system office in Atlantic City.

W. H. Spahn gave an illustrated talk on probability and its relation to engineering problems before the Cooper Union Mathematical Club.

General Staff

S. P. Grace addressed the Telephone Pioneers of America at Boston on November 2, the Cleveland Engineering Society on November 13, and the Baltimore Chamber of Commerce on November 27. On each occasion he spoke on the recent Laboratories developments.

S. P. Grace, W. C. F. Farnell, C. L. Goodrum, and G. F. Morrison, members of E. J. Hall Chapter of Telephone Pioneers, attended the Pioneers' convention at Boston.

L. S. O'Roark spoke to the Syracuse Section of the A.I.E.E. on "Electrical Transmission of Personality."

J. S. Hartnett has been appointed a member of the Finance Committee of the New York Junior Board of Trade.

R. W. King has been transferred to the Department of Development and Research of the American Telephone and Telegraph Company. He is to be associated with H. E. Shreeve, that Company's Technical Representative in Europe, and his headquarters will be in London.

James W. Brown, of the Personnel Department, died on Sunday, November 4. Mr. Brown became a member of the Laboratories on July 14, 1926, and since that time had been on the staff of the Educational Department, engaged in instructing student assistants.

Inspection Engineering

A. F. Gilson visited Hawthorne during the week of October 29, in connection with his new duties as Assistant Inspection Engineer.

A recent change in the Field Engineering Force involves the assignment of H. J. Knowlton as Field Engineer in Chicago, replacing I. W. Whiteside, who will return to New York. G. D. Edwards visited Chicago during the week of November 12, to introduce Mr. Knowlton to Western Electric and Telephone

Company people in Chicago and Milwaukee.

As a part of the program of regular supervisory visits to Field Headquarters, A. G. Dalton spent the latter part of the week of November 5 in Atlanta with T. L. Oliver.

R. M. Moody and A. Grendon were at Hawthorne during the week of October 22 attending a regular Inspection Survey Conference on handset mounting. O. S. Markuson was at Hawthorne during the following week, also in connection with Inspection Survey Conference work.

E. G. D. Paterson represented the Inspection Engineering Department at a conference on the inspection of construction equipment, held on November 13 at the Highway Trailer Company plant in Edgemont, Wisconsin.

H. F. Korthеuer and T. Mellors attended Equipment Survey Conferences at Kearny and Hawthorne, respectively, during the early part of November.

S. H. Anderson and D. S. Bender were in Hartford on October 31 to invesigate the operation of step-by-step P.B.X. power plants.

Outside Plant Development

On October third, S. C. Miller and C. H. Amadon visited Boston where they conferred with engineers of the New England Telephone and Telegraph Company relative to requirements for chestnut poles.

J. M. Hardesty with L. B. Spengeman of the Western Electric Company visited Pittsfield, Mass., on October 26 in connection with matters relating to the manufacture of clay conduit.

On October twenty-third, E. M. Honan and F. F. Farnsworth inspected the laboratories of the New Jersey Zinc Company at Palmerton, Pennsylvania.

C. Shafer, Jr. and W. T. Jervey visited New Haven and Bridgeport on October 9 and 10 in connection with a field trial of a modified porcelain knob for parallel drop wire. From October 29 to October 31, Mr. Jervey visited the Corning Glass Works at Corning, New York, in connection with tests of Pyrex insulators.

On October twenty-second, C D. Hocker made development studies at New Britain, Connecticut, on fittings for linemen's body belts and safety straps. From October 29 to October 31, Mr. Hocker examined galvanized sheet metal samples which have been exposed to weather at Pittsburgh, Altoona, and State College, Pennsylvania, and Sandy Hook.

On October fifteenth, F. F. Farnsworth was in Washington making studies of paint testing apparatus in the Bureau of Standards laboratory and in the Henry A. Gardner Laboratories. Mr. Farnsworth attended a committee meeting of the American Society for Testing Materials at Schenectady on October 18 where the effects of outdoor exposure on zinc coated hardware and wire were discussed.

During October R. H. Colley visited Denver, Colorado, for the purpose of determining the condition of western cedar and lodge pole pine poles in service in the Limon Colorado-Sharon Springs toll line.

C. S. Gordon attended the annual convention of the American Society for Steel Treating in Philadelphia on October 9 and 10.

Election of Club Officers

THE candidates for Bell Laboratories Club offices for the year 1929 have been selected by the nominating committee. Ballots will be mailed to all club members on Friday, December 14 and must be placed in the ballot boxes Monday, December 17, between the hours of 8:30 A.M. and 6 P.M. Ballot boxes will be located in prominent places in each section on all floors of the building. No employee who is not a member of the club will receive a ballot. Club membership application forms may be obtained from Departmental Representatives or from the Club Secretary. Applications received after December 12 will not entitle new members to vote in the current elections.

The nominating committee which selected the candidates consists of D. A. Quarles, D. D. Haggerty, A. L. Johnsrud, S. J. Stranahan, J. C. Kennelty, T. J. O'Neil, P. J. Higgins, G. Rupp and T. C. Rice. The candidates:

For President

H. A. Frederick
O. M. Glunt

For First Vice-President

G. H. Heydt
H. F. Dodge

For Second Vice-President

Miss M. F. Kane
Miss M. Horne

Departmental Representatives

Two Year Term

Systems Development

P. B. Fairlamb
N. H. Thorn

Research

F. W. Hultqvist
J. G. Knapp

Commercial

J. C. Kennelty
G. A. Brodley

Tube Shop

W. D. Stratton
A. C. Thoesen

Nominated for Club President



Halsey A. Frederick

Here we show you Halsey Frederick, a candidate for the Club presidency. Mr. Frederick had his university training at Princeton, where he was prominent in undergraduate musical activities. On graduation he entered the Laboratories, where his first work was on mechanical repeaters. The war period saw him interested in submarine signalling, sound ranging, and aircraft detection. In recent years Mr. Frederick has had charge of a continuous program of research on telephone transmitters and receivers.

Mr. Frederick continues his musical interests, and is President of the Mountain Lakes Glee Club. He may be counted on to foster the Club's numerous activities in this field, and to balance the Club's program by encouraging athletic and social events.

Nominated for Club President



Omer M. Glunt

We present to you Omer M. Glunt, candidate for the Club presidency. During his undergraduate years at Ohio State University he assisted in the organization of social activities and was generally active in college affairs. Two years and more of the Manufacturing and Installation Departments served to broaden his viewpoint. In 1911 he came to the Laboratories, continuing his work of apparatus design. At present he directs the development of special products. Among these are talking motion-pictures, radio broadcasting transmitters, airplane communication by radio, and power line carrier telephone.

Mr. Glunt swings a wicked rod over the surf on the Jersey shore; when the finny monsters are not biting he takes a hand at bridge or a round at golf. He has always shown a broad interest in the Club, and may be counted on to support progressive policies.

FOR FIRST VICE-PRESIDENT

G. H. HEYDT





H. F. DODGE

HERE are the candidates for First Vice-President of the Club: Mr. Dodge is engaged in Inspection Engineering — specifically, he has charge of inspection methods and results. Mr. Heydt is a member of the Patent Department, where he protects our patent rights on talking motion picture developments. Mr. Heydt is a graduate of Lafayette, and Mr. Dodge of M. I. T. Both have served the Club as departmental representatives.

FOR SECOND VICE-PRESIDENT



Margaret Horne

Marian Kane



ABOVE are the candidates for Second Vice-President of the Club. Miss Kane is a member of the Patent Department. She has taken a keen interest in the women's activities of the Club since its beginning; she has been a regular member of the swimming class and bowling club. Miss Horne, as chairman of the committee on women's interests, has been an important factor of the Club during the year 1927, and has always been active in its behalf. She is a member of the Research Department.

For Departmental Representative

SYSTEMS DEVELOPMENT



Norman H. Thorn



Preston B. Fairlamb

TUBE SHOP



Alvin C. Thoesen



W. D. Stratton

For Departmental Representative

RESEARCH DEPARTMENT



Ferdinand W. Hultqvist



John G. Knapp

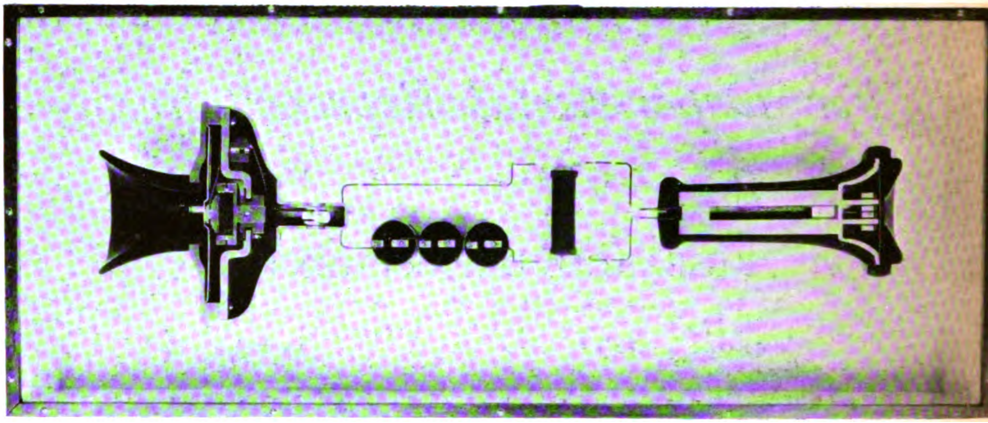
COMMERCIAL DEPARTMENT



George A. Brodley



Joseph C. Kennelty



Graphic Model Presented to National Museum

Enlarged sectional models of transmitter and receiver simulate operation

FORMAL presentation of a sectional model of a telephone transmitter and receiver, whose diaphragms can be vibrated in synchronism by an observer to illustrate the fundamental mechanism of telephony, was made to the United States National Museum of the Smithsonian Institution on October 24. In the model, illustrated above, the instruments are connected by an elementary transmission circuit, such as is used where no provision is wanted for switching or amplification. Demonstration of its working is obtained by means of a lever at the bottom of the case, connected through a linkage to the diaphragms of both instruments. When moved slowly back and forth the lever vibrates the transmitter diaphragm as would sound waves impinging upon it, and thereby compresses and releases the carbon granules of the resistance button. At the same time it vibrates the receiver diaphragm by means of mechanical linkage as if voice currents were passing through the transmission circuit.

For clarity of detail, transmitter and receiver are each four times the standard size; and the dry cells and induction coil are of the normal size. The model is enclosed in a mahogany case about four and a half by two feet, with a plate glass top. Instruments and case were constructed in the Engineering Shop of the Laboratories. A special table is to be provided by the Museum on which the model will be displayed; it will adjoin the Alexander Graham Bell Exhibit.

The presentation was made on behalf of the American Telephone and Telegraph Company and Bell Telephone Laboratories by G. K. Thompson of the American Company and W. C. F. Farnell, Curator of the Bell System Historical Museum. Dr. C. G. Abbot, Secretary of the Smithsonian Institution, received the exhibit for the Museum, and subsequently wrote to Dr. Jewett to express his appreciation.

Club Calendar for December

MONDAY, 3: Basketball, Men, Bell System League Tournament, Stuyvesant High School, 8:30
Basketball, Women, St. Luke's gymnasium, 5:30
Bridge, Men, Room 275, 6:00
Swimming Class, Women, Carroll Club, 7:00

TUESDAY, 4: Basketball, Men, Labor Temple, 5:30
Indoor Golf Tournament, Women, Vander-Built-In Course

WEDNESDAY, 5: Basketball, Men and Women, Bell System League Tournament, Erasmus Hall High School, 7:30
Glee Club, Rest Room, 5:10
Swimming Class, Women, Carroll Club, 5:30
Indoor Golf Tournament, Men

THURSDAY, 6: Basketball, Men, Labor Temple, 5:30
Orchestra Rehearsal, 11th floor Rest Room, 6:00

FRIDAY, 7: Bowling, Men, Dwyers Manhattan Alleys, 5:45
Bowling, Women, Dwyers Manhattan Alleys, 5:45
Bridge, Women, Rest Room, 5:10
Basketball, Men, Bell System League Tournament, Stuyvesant High School, 8:30

SATURDAY, 8: Chess Match, Commercial Chess League Tournament, 463 West Street

MONDAY, 10: Basketball, Men, Bell System League Tournament, Stuyvesant High School, 8:30
Basketball, Women, St. Luke's gymnasium, 5:30
Bridge, Men, Room 275, 6:00

TUESDAY, 11: Basketball, Men, Labor Temple, 5:30

WEDNESDAY, 12: Basketball, Men and Women, Bell System League Tournament, Erasmus Hall High School, 7:30
Glee Club, Rest Room, 5:10

THURSDAY, 13: Basketball, Men, Labor Temple, 5:30
Orchestra Rehearsal, 11th floor Rest Room, 6:00

FRIDAY, 14: Bowling, Men, 5:45
Bowling Women, 5:45
Bridge, Women, Rest Room, 5:10
Basketball, Men, Bell System League Tournament, Stuyvesant High School, 8:30; dancing after game

MONDAY, 17: Basketball, Women, St. Lukes gymnasium, 5:30
Bridge, Men, Room 275, 6:00

TUESDAY, 18: Basketball, Men, Labor Temple, 5:30

WEDNESDAY, 19: Basketball, Men and Women, Bell System League Tournament, Erasmus Hall High School, 7:30; dancing after game
Glee Club, Rest Room, 5:10

THURSDAY, 20: Basketball, Men, Labor Temple, 5:30
Orchestra Rehearsal, 11th floor Rest Room, 6:00

FRIDAY, 21: Bowling, Men, 5:45
Bowling Women, 5:45
Basketball, Men, Bell System League Tournament, Stuyvesant High School, 8:30

SATURDAY, 22: Chess Match, Commercial Chess League Tournament, McGraw-Hill

WEDNESDAY, 26: Glee Club, Rest Room, 5:10

THURSDAY, 27: Orchestra Rehearsal, 11th floor Rest Room, 6:00

FRIDAY, 28: Bowling, Men, 5:45
Bowling, Women, 5:45

MONDAY, 31: Basketball, Women, St. Lukes gymnasium, 5:30

BELL LABORATORIES RECORD

PARTICLES AND WAVES
By K. K. Darrow

E. P. CLIFFORD

REGULATION FOR TOLL CABLES
By E. D. Johnson

JANUARY 1929 VOL. 7 NO. 5

Bell Laboratories
Record

A Monthly Magazine of Information for Members of
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Bell Laboratories Record

Volume Seven | January, 1929 | *Number Five*

To The Men and Women of Bell Telephone Laboratories

A year ago I ventured to look into the future of 1928 *and to see there a picture of achievement of interest to us all. The accomplishments of the twelve months just past have fully justified that picture. As we come once more to the turning of the page to another new year, one and all we are curious as to what we shall find there.*

Viewing the vast array of problems which confront us — problems which arise out of the irresistible pressure in the Bell System for enlarged service or from those great new industries which are building on the basis of our work — it is clear that we have a job to do in 1929.

For twenty-five years I have been a part of the research and development organization of the Bell System. In all that period there has never been a time when the work immediately ahead bulked so large either relatively or absolutely. The problems which now confront us are numerous, vast and intricate almost beyond belief. Their solution will tax to the limit our ability, ingenuity, organizng capacity and energy.

None of us is afraid of such a challenge; and since the substantial satisfactions of life are the memories of constructive work well done, we can one and all welcome the opportunity to show what manner of men and women we are.

My greetings of the Season are tempered by the sadness which we all feel at the sudden and untimely loss of our friend and associate, Vice-President Clifford.

FRANK B. JEWETT.

Particles and Waves

By KARL K. DARROW
Research Department

WHEN we read in the morning paper that it rained yesterday in Chicago and the day before in North Dakota, and presently look out of the window and see clouds gathering in the Western sky, we think it natural to say "the rain is arriving from the West." This, however, is loose language; but to say precisely what it is that is arriving from the West would require more knowledge than most of us possess, more perhaps than the greatest weather experts can justly claim. Certainly the water which is about to descend into the streets of Manhattan was not over Illinois yesterday. Probably it was suspended not many miles away from New York as invisible vapor in the sky, when the air suddenly grew cooler and it began to condense into visible cloud. What came from the West at the speed of an express train was not the substance of the cloud, but the fall in the temperature of the air, or some other state of the atmosphere, which created the cloud in its footsteps as it raced along. Rain, of course, is more intelligible. What goes from the clouds to the pavements is matter in motion, individual corpuscles of water which go as units through the air until they splatter upon the ground or are swallowed up into the rivers. When a raindrop falls into water, its identity is gone forever; but for a time there are ripples spreading in widening circles over the water-mirror from the place where the drop ceased to exist. The ripples seem to have inherited the motion of the raindrop; but their onward march is not motion of substance. The water is not flowing away from the place where the raindrop perished; the water is only heaving up and down; what moves away is a mere form or molding of its surface, even less palpable than the travelling fall in temperature which brought about the coming of the rain.

Now this little history of the rainstorm exhibits three kinds of motion only one of which is strictly motion of matter; and since the study and the forecasting of motion is one of the major objects of science, we find here three problems to set before the architects of physics. Only the second of the three was solved by Newton in his masterpiece, the *Principia,* in which he founded the "classical" mechanics. The "Laws of Motion" which Newton gave as the foundation for mechanics were laws of the motion of matter. He solved, for instance, the problem of the projectile, and traced the path for the cannonball to follow after it leaves the cannon's mouth. Were it not for forces, Newton said, the ball would continue onward in a straight line forever; but the earth exerts a force upon it, and so it bends its course along an arc which brings it back to earth again in the predicted spot. The roar of the gun, however, is not a piece of

metal, but a wave; and its motion is not subject to the laws of Newton.

Examining, however, the journey of the roar of the gun, one finds that it is not altogether unlike the journey of the ball. We know—though the knowledge was not available to Newton—that the sound of the shot, having risen into the sky, may bend over and come down again to earth at a great distance, so that beyond a broad zone of silence the gun is audible. Could we make visible the track of a particular section of the wavefront of the explosion-wave, a section starting nearly vertically upward, we should occasionally see it as an arch in the high air, like though not exactly the same as the arched trajectory of the cannonball. Short radio waves have at times the same habit of rising up from the broadcasting aerial, overarching wide tracts of land where it is vain to try to detect them, and descending to be received by listeners far away.

Now it is said that the cannonball descends because the earth pulls it downward out of the straight course which it otherwise would follow into the depths of space. Are the waves also drawn downward by some force out of a straight path in which otherwise they would continue? It is not necessary to imagine such a force; it is sufficient to recall that the speed of the waves varies from point to point in the air. At times the air is warmer several miles overhead than near the ground. When a section of a wavefront ascends obliquely into this warmer stratum, its higher part advances faster than its lower part, and the wavefront is tilted gradually over—one might say that at the start it is leaning backward, and bends forward, eventually standing vertical, then leaning forward and finally plunging downward to earth. The radio waves which "skip" long distances behave in the same way: their wavefronts are gradually tilted over and down because they move faster in the upper air than in the lower, though the cause of the greater speed in the higher atmosphere is not increase of warmth but an abundance of free electrons. For the same reason light is refracted when entering water obliquely from air; the part of the wavefront which is first to dive is also first to be slowed down, and the whole wave is wheeled around until it moves in a direction more nearly perpendicular to the interface of air and water.

Different reasons, therefore, are given to explain why waves on the one hand, projectiles on the other, deviate from the straight course: the "cause" in the one case is described as a variation of the wave-speed from point to point in the medium, in the other case as an external field of force prevailing at every point of space. Now when we come to express these two explanations in mathematical form we find (as not infrequently happens in mathematical physics) that the two sets of equations display strong resemblances, which are not in the least evident to a mere casual contemplation of the seemingly very different pictures which they describe. The picture of an external force-field and the picture of a variable wave-speed are in essence much more alike than they seem. Indeed it is permissible to say that the cannonball, travelling along its parabolic arc from the cannon's mouth into the sky and back to the ground, is riding upon an invisible wave which carries it along like a parcel; the motion of the ball is controlled by the motion of the wave,

which is determined by the variation of the wave-speed from point to point. It is easy to formulate the way in which the speed of this imaginary wave must depend upon height above the ground-level, in order to explain the motion of the projectile. One of the Bernoulli family did it more than two centuries ago. One might imagine the space around the earth to be filled with an aether, able to carry waves with a wave-speed prescribed in the proper way; the firing of the gun would be supposed to create a mighty wave, which carried the projectile on its back. There would have to be a different aether for every different choice of initial velocity for the cannonball, which makes the picture rather clumsy; yet it might present advantages great enough to make even this clumsiness endurable.

The waves of the foregoing picture are not precisely the waves which de Broglie invented and Schroedinger adapted, thus founding the new "undulatory mechanics" or "wave-mechanics"; but the two kinds are sufficiently alike for either to serve excellently as an introduction to the other. As a matter of fact, the "de Broglie waves" for the cannonball trace the proper parabolic arc, but move much faster than the ball, which therefore cannot be thought of as riding upon them. (The speed of the ball is the "group-speed" of the de Broglie waves—a concept which however is a little too intricate to be explained here, although it is familiar in optics). The waves of de Broglie and Schroedinger are endowed, however, with another feature, which I will now illustrate by an example from acoustics.

Suppose a tensed piano-wire infinitely long; suppose it plucked at a certain point, or preferably set into continuous simple-harmonic vibration by a tuning-fork pressed against it. A wave of distortion starts from the place where the sidewise push or pull is applied, and travels indefinitely along the wire with a constant speed. Suppose now that the length of the wire is limited, say by cutting it in two places and attaching the ends firmly to walls. We will suppose for convenience that the tuning-fork is pressed against the midpoint of the wire between the walls. The waves travel from the fork along the wire to the walls, are reflected, return, meet new waves and combine with them, are again reflected from the opposite walls, meet additional waves and coalesce with these, and so forth; and eventually a "steady state" is attained, in which the motion of the wire is in general very complex. It is, however, a matter of common knowledge that if a certain condition is satisfied—if the frequency of the tuning-fork is properly adjusted to the length of the wire and to the speed of the waves, which last is determined by the tension of the wire—then the motion of the wire becomes both simple and vigorous. If, for instance, the frequency of the fork is made equal to the "fundamental frequency" of the wire, which can easily be computed from its length and from the wave-speed, then the particles of the wire vibrate with an amplitude which increases steadily from both ends to the centre. A loud musical tone is heard from the wire, and to the eye it seems to be spread into a ribbon of which the breadth varies as a sine-curve, or rather would so vary if the force were properly applied. This "ribbon" is a wave-pattern; and when the frequency of the fork, which is the frequency of the

waves, is adjusted to agree with any one of the natural frequencies of the wire—its fundamental or any overtone—a wave-pattern characteristic of that frequency appears. This is called the phenomenon of *resonance*. A like effect would occur if the wire were bent into a closed ring. Here resonance would take place when the frequency of the waves was so adjusted that each wave on completing the circuit found another just starting on the course.

Frequency is the new feature which de Broglie introduced into the waves which I earlier mentioned, the "phase-waves." Frequency implies the possibility of resonance; frequency implies diffraction, interference, perhaps polarization, a variety of properties of light and sound which could be looked for and might be found. Suppose, for instance, that the Bernoulli waves which I described at first, which may be conceived to carry the cannonball in its flight, were endowed with a special frequency and wave-length; might it be possible to generate them inside a box of dimensions so chosen that they would enter into resonance, and the resonance be detected in some peculiar way? The idea seems a wild one; but the atom-model of de Broglie and Schroedinger is developed from one like it.

For twenty years it has been accepted that a hydrogen atom is composed of a positively-charged nucleus and an electron revolving around it, sometimes in a circular orbit. In order to explain the properties of this atom, it is necessary to assume that out of all the infinity of conceivable circular orbits of various radii, only a few are "permitted" to the electron; we know which these permitted ones must be. Now let us follow de Broglie and correlate with the electron a stream of waves. Like the Bernoulli waves they shall rush around and around the orbit of the electron, but unlike the Bernoulli waves they shall not have its speed. Their wave-speed shall depend upon distance from the nucleus of the atom, as the speed of the Bernoulli waves associated with the cannonball depended on height above the ground, although not according to the same law. The choice of the law of dependence of the wave-speed upon the distance is the chief step in the design of the atom-model; one might envisage it as the invention of a special kind of aether filling the space in and around the hydrogen atom, designed to carry waves with a wave-speed varying from point to point according to a law specially chosen. Finally, these electron-waves shall have a special frequency, proportional to the energy of the system composed of electron and nucleus, which is the atom itself.

When all these assumptions are made, and the law of the wave-speed properly chosen, it turns out that the permitted circular orbits are precisely those on which the electron-waves so overlap one another that they form a stationary wave-pattern, and resonance occurs. Were we to take a circular orbit at random we should probably find that the overlapping was such as to produce a very confused and intricate vibration, like the motion of a piano-wire forced to vibrate by a fork not tuned to any of its natural frequencies. But for the permitted circular orbits the wave-motion in the imaginary aether pervading the hydrogen atom is of the simple character of the motion of the wire stimulated by a fork having one of its own natural frequencies.

Viewed in this way, the problem of

the atom becomes the same as the great problem of acoustics: to find the natural frequencies of a body capable of vibration. The problem of the oscillating electron becomes like that of the piano-wire; the problem of the revolving molecule like that of the telephone-diaphragm; the problem of the hydrogen atom like that of the ball of fluid. They are more intricate than their acoustic analogues, for in the wire or the sphere of fluid the wave-speed of the sound-waves is everywhere the same, while in the "imaginary string" used as symbol for the oscillating electron and in the "imaginary fluid" used as model for the hydrogen atom, the wave-speed must be supposed to vary from point to point in a peculiar and characteristic way—the selection of this way being, as I said before, the chief step in the building of the theory. *En revanche,* this variability of wave-speed is precisely what makes the problems soluble. When we are dealing with an actual wire, membrane or fluid, we get resonance only when they are bounded—when the wire is cut off and clamped at the ends, the membrane cut into a circuit and clamped around the edge, the fluid contained within a rigid hollow sphere. But the imaginary strings and membranes and fluids of the atomic theory have resonances even though they continue to infinity; and these resonances correspond to the Stationary States of the atoms, from which most of their qualities are derived.

One more example: if an electron is attended by waves moving along the same path, and a beam of electrons moving along parallel lines is therefore escorted by a beam of parallel waves, may not these waves be diffracted by a grating as light-waves are? and may they not carry electrons into the diffraction-fringes as Bernoulli's waves were thought to carry the cannonball (though here again the speeds are not equal), so that in effect the electrons will be diffracted? On computing the wave-lengths which, in order to make the model for the hydrogen atom valid, must be assigned to electrons of given speeds, it is found that those associated with electrons of the speeds ordinarily occurring in discharge-tubes are of the magnitude of the wavelengths of X-rays. We must, therefore, use natural crystal gratings such as are used with X-rays. Carrying this idea (which first occurred to a young German student named Elsasser) into practice, Davisson and Germer discovered that electrons are in fact diffracted as are waves of the calculated wavelength.

We are therefore confronted with the amazing fact that the phase-waves, conceived purely as a mathematical artifice, seemingly differing from matter and electricity as the visions of the mind differ from the common-sense actuality of the solid physical world, have nevertheless acquired a reality ranking with the reality of things visible and things tangible. Indeed theirs may be even the stronger; for when the equations describing the resonances of the hydrogen atom are actually derived and written down, the electron and the nucleus are no longer obvious in them, and nothing remains but the wave-pattern. It is as though at a concert the air which carries the music and the instruments of the orchestra and the players themselves should be proclaimed unreal, and nothing remain but the music.

Transmission Regulating System for Toll Cables

By E. D. JOHNSON
Systems Development Department

EXPOSED to sun, wind, rain and sleet, an aerial telephone cable varies in temperature over a wide range. Changes result in resistance of the conductors and, to a lesser degree, in dielectric capacity, with accompanying changes in attenuation of the speech currents. For the cables in the exchange plant, and for the shorter toll cables, these changes may be disregarded, but for the long toll cables they make necessary frequent readjustment of repeater gains to keep the net loss of each circuit within the rather close limits specified. The readjustment is effected by an automatic regulator, which derives its information as to conditions in the cable from the change in resistance of a metallic circuit. The regulator is essentially an automatic Wheatstone bridge whose rebalancing mechanism controls also the telephone repeaters.

In applying the regulating system the cable is divided into sections usually from one to two hundred miles in length. Generally, all circuits passing through each section are automatically compensated by one "master regulator" placed at a repeater station near the center of the section.

Two cable-pairs, extending in opposite directions, are short-circuited at their distant ends, and resistances are connected in series with the shorter pair. Thus approximately equalized, the pairs are connected in parallel to form one arm of the bridge.

When the temperature, and conse-

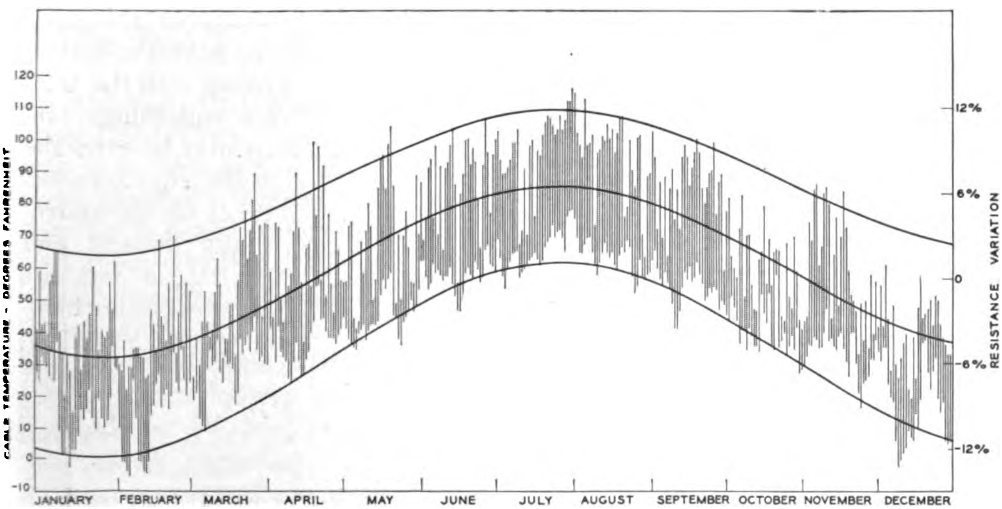


Fig. 1—Why automatic regulation is necessary—daily variations of temperature along the New York-Chicago Cable

quently the resistance, of the pilot wire changes, the Wheatstone bridge is thrown out of balance, and the galvanometer deflects. This galvanometer is part of a Leeds and Northrup motor-driven recorder. At intervals of a few seconds the driving

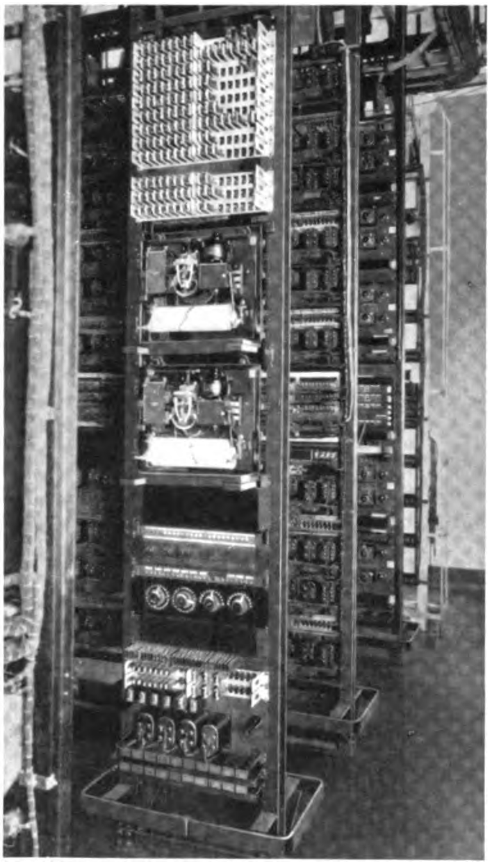


Fig. 2 — A regulator panel installed at Allentown on the New York-Chicago cable. At the top are the relays; next the "spare" and the "regular" regulator; then the lamps which indicate the regulator position; control keys; test jacks, dial-switches, and miscellaneous apparatus

motor, through a cross-bar, lifts the pointer of the galvanometer so that, if deflected, the pointer in turn raises one or the other of two levers. If not deflected, that is, when the bridge is in balance, the pointer passes between the ends of the two levers. Through an ingenious mechanical system, the raising of either lever causes a shaft to be rotated through a small angle, whose amount depends on the galvanometer deflection and whose direction depends on which lever is raised. The shaft in turn operates a slide-wire resistance to restore the balance of the bridge, and also moves the arm of a dial switch over a series of contact-points connected to a group of relays, which in turn readjust the gain of the associated repeaters. In the case of 19 gauge H-174* circuits where the changes in transmission are substantially the same at different frequencies throughout the voice range, simple resistance potentiometers can be used to regulate the gains of the repeaters. In the case of 19 gauge H-44-25** circuits, however, difficulty was encountered in the fact that changes in transmission at low frequencies produced by a given resistance change are less than those at high frequencies. More complicated networks were therefore required to vary the gain differently at different frequencies.

There are ten steps on each side of the "zero" position of the dial switch; that one which is in contact with the arm is indicated by a lighted lamp on the control panel. The central "zero" step is symbolized by a green lamp; the extremities by red lamps and the remaining steps by white lamps. Should the regulator stop with the arm bridging two contacts, the relays change the gain by one-half the amount of a full step. A permanent record is made by a pen travelling

* *Sometimes called "medium heavy loaded."*

** *Sometimes called "extra light loaded."*

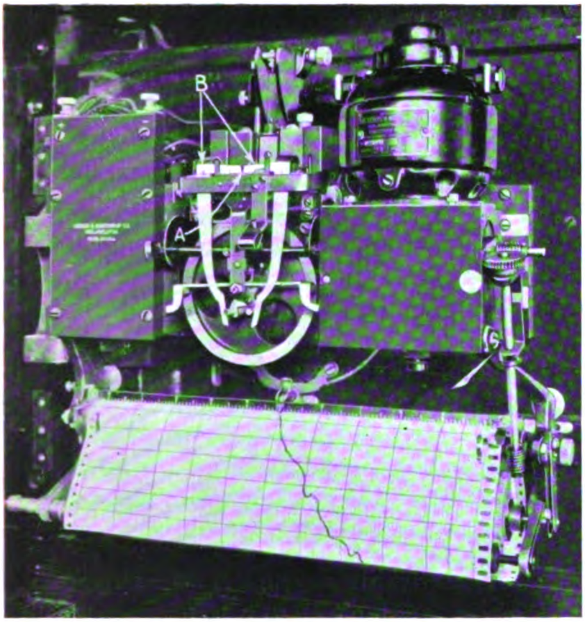


Fig. 3—A close-up of the Leeds and Northrup recorder which is the heart of the system

provided; its operation short-circuits the galvanometer and operates the lamp and buzzer signals continuously. In both these cases, disappearance of the trouble restores the apparatus to its normal operation.

Under extreme conditions of temperature, or for other reasons, the resistance of the pilot wire may change beyond the ability of the regulator to follow it. On the tenth step of the dial switch, a contact is closed which stops the driving motor, disconnects the battery supply from the bridge and operates the buzzer. As soon as circuit readjustments have been made, the attendant sets the dial switch on the ninth step and places the apparatus again in operation. Should the trouble persist, the regulator would advance to the tenth step and the alarm would again be given.

across a chart which in turn is advanced by the motor at one and one-half inches an hour.

Trouble on the pilot wire, such as an open or short circuit, looks to the regulator like a sudden large change in the attenuation of the cable. Doing its best to meet the emergency, the regulator would change the repeater gains quickly through a considerable range, perhaps even to the limit of its ability, with disastrous results on telephone transmission. By an ingenious mechanical modification of the mechanism, the galvanometer is prevented from operating the bridge in case of a large deflection, but instead intermittently lights a lamp and sounds an alarm buzzer. Still greater unbalance of the bridge might send so much current through the galvanometer as to endanger its winding. A relay with differential windings in two of the bridge arms is therefore

Direct current at 110 to 130 volts is required for the bridge circuit from

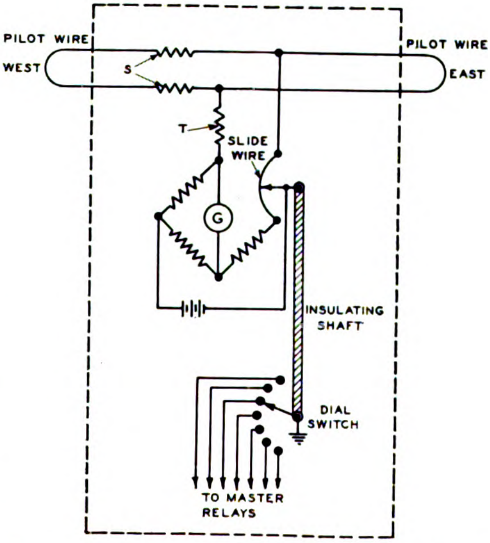


Fig. 4—The Wheatstone bridge circuit in simplified form

an ungrounded battery. Since the current drain is only about twenty-five milliamperes, either dry or storage cells may be used. Failure of this current-supply lights a lamp and operates the buzzer. Current for the motor is drawn from the 24-volt battery.

Ideally, the pilot-wire should be loaded in the same way as the telephone circuits which it is to control. The regulator has been designed for use with 19 gauge H-44-25 pilot wires, since these circuits require the most accurate regulation, and field trials have shown that other types of circuits are then controlled with sufficient accuracy. Non-loaded 19 gauge pairs may also be used. Spare pairs may be used as pilot wires, or a metallic (ungrounded) circuit may be obtained by use of two composited telegraph circuits connected at their distant end. To balance out the composite coils, whose temperature-change is that of central-office air, a number of resistances wound with copper wire are included in the regulator circuit.

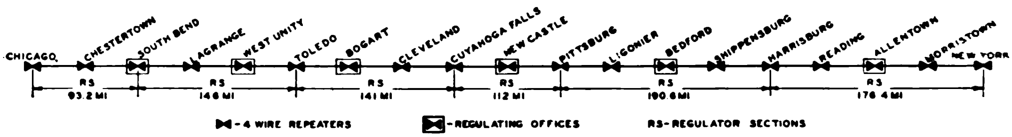


Fig. 5—How regulators and repeaters are spaced on the New York-Chicago Cable

Setting a transmission regulator in operation requires, beside the installation and mechanical test of the apparatus, some careful tests of the lines involved. The zero position of the slide-wire corresponds to an average temperature of the pilot wire of fifty-five degrees F. In general, the cable at the time of test will be at a different temperature, so the slide wire must be set at some other point. Knowing the theoretical resistance of the pilot wire at fifty-five degrees, and adding to this value the nominal resistance of the composite coils, if any, it is possible by comparison with the measured resistance of the cable to determine where the slide wire should be set at the time of installation.

The regulator motor having been started, the battery circuit is closed. If necessary, the bridge is balanced by adjusting resistances *T* and *S*. Finally, transmission measurements with 1000-cycle current are made on one or more of the 19 gauge H-44-25 circuits to be regulated. With individual repeaters adjusted to give their specified gains, the overall transmission equivalent of the circuit must be that specified to within 0.2 db; otherwise the resistances *T* and *S* are varied to secure the required agreement.

Regulators are installed along all long-distance cables; for example, between New York and Chicago there are regulators at Allentown, Bedford, New Castle, Bogart, West Unity and South Bend. In the area covered by the Long Lines cable plant, about 4 of these devices are constantly on guard to help maintain satisfactory telephone transmission.

Corrosion of Lead Cable Sheath

By R. M. BURNS
Research Department

CORROSION is a term used to describe the reaction of a metal to elements of its environment such as water, oxygen, carbon dioxide, gaseous sulfur compounds, acids, alkalies and salts. All metals corrode but in many cases the product of corrosion is a protective film which retards or prevents continuation of the action. A film is protective only if it is adherent to the metal, continuous, and insoluble in the surrounding medium. Films which are not continuous may modify or even accelerate the rate of corrosion.

Lead forms protective films under certain conditions. For instance when exposed to the atmosphere it tarnishes and becomes inert owing to the formation of an oxide film which increases in thickness during a period of about ten days. In the presence of moisture and carbon dioxide, lead becomes coated with a film of lead carbonate. While this film considerably reduces the rate of corrosion it does not prevent corrosion. The carbonate film forms when a small amount of carbon dioxide is present, and the rate of corrosion is then governed by the rate at which oxygen permeates or diffuses through the film. A third kind of film is formed on lead by small amounts of soluble silicates. The existence of this film on the surface of lead prevents its corrosion in slightly acid, neutral or slightly alkaline solutions. Under high conditions of alkalinity, however, this film dissolves and is no longer protective.

Corrosion, according to the modern viewpoint, is an electrolytic process. It depends upon the existence of small potential differences between different points on the metal surface, making tiny batteries, and upon the character of the reactions which occur at the electrodes as a result of the flow of small electrical currents. The fundamental reaction for the corrosion of lead may be represented by the equation:

$$\left.\begin{matrix}\text{Lead atom} + \\ \text{2 hydrogen ions}\end{matrix}\right\} = \left\{\begin{matrix}\text{Lead ion} + \\ \text{2 hydrogen atoms}\end{matrix}\right.$$

This is merely a statement of the fact that metallic lead dissolves at anodic areas and that hydrogen "plates out" as atoms on cathodic areas. There is formed in this way a film of atomic hydrogen which must be removed if corrosion is to proceed, the rate of corrosion being dependent upon the rate of removal. The process of hydrogen removal consists either in evolution as hydrogen gas or in oxidation. From a lead surface there is little tendency to evolve hydrogen even in highly acidic solutions. If however there are present other metals or substances such as copper, iron, carbon, etc. which more readily discharge hydrogen as a gas, corrosion is accelerated. More commonly hydrogen is removed from these cathodic areas by oxygen or oxidizing substances with the formation of water, and for this reason the

rate of corrosion is determined generally by the rate at which oxygen reaches the lead surface undergoing corrosion.

Certain secondary reactions occurring at the electrodes often influence corrosion. For instance, the products of electrolysis may offer resistance to the flow of current or may by film formation on anode areas reduce or prevent dissolution of the metal. In the latter case current flow may continue, the anode process consisting of gas evolution (usually oxygen). On the other hand, electrolysis may result in the formation of a substance which is corrosive to the metal. For example, alkali and lime salts are converted into caustic alkali and free lime at the cathode and these attack lead.

A knowledge of the relationship of anode and cathode potentials to current density, make it possible to predict under given conditions whether or not a metal is likely to corrode. The influence of surrounding conditions may be illustrated by the behavior of lead in solutions of acetic acid, in which it dissolves readily, and in solutions of sulfuric acid, in which it is but slightly soluble. In the former case small potentials yield high current densities (corresponding to high rates of corrosion) while in the latter case relatively high potentials are required to maintain even moderate current densities. Moreover in this latter case formation of a lead sulfate film on the anode prevents corrosion at current densities corresponding to appreciable rates of corrosion.

The sheathing used for telephone cables consists of lead or more generally an alloy of lead and one per cent of antimony. While the alloy is somewhat more resistant to corrosion than is lead, the corrosion reactions in the two cases are similar and for the purposes of this paper may be considered as identical.

There are from a practical standpoint four kinds of corrosion to which cable sheath is subject. These are characterized as (1) soil or soil water, (2) acetic acid or white lead, (3) stray current anodic or ordinary electrolytic, and (4) stray current cathodic or negative corrosion. Fundamentally, these types of corrosion are all electrolytic and involve the same mechanism, the distinction between them having to do mainly with the source of potentials responsible for corrosion. In the first two classes the potentials are galvanic in type and arise from a lack of homogeneity either in the metal or in the medium adjacent to it; the third type, stray current anodic, is due to potentials picked up from improperly insulated power circuits, i.e., street railway, light and power lines; and the last class, stray current cathodic, is a combination of the galvanic and stray current types or in the ordinary sense a chemical reaction between the cable sheath and caustic alkali or free lime generated by electrolysis when the sheath is cathodic or negative to earth.

Whether a metal is corroded uniformly or pitted locally depends upon the area, position and number of anodes in a small area. If the anodes are large in area or numerous the attack tends to be uniform in appearance. This is illustrated in the corrosion of lead in acetic acid. If the anodes are widely separated or of small area with respect to the area of the lead surface, then the attack is of a pitting nature. In the case of cable sheath pitting action is the more dangerous since it produces perfora-

tion of the sheath in a shorter time.

While soil corrosion is not a serious problem in cable maintenance, occasional cases are reported. It is due generally to exposure of different parts of the sheath to different concentrations of oxygen, salts, acids or alkalies. Pitting action initiated by stray current electrolysis may continue after elimination of the positive potential conditions owing to the fact that the pits, being less accessible to oxygen, become the anodes of galvanic cells which eventually cause perforation of the sheath. This is doubtless the explanation of many cases of "old action." Soil corrosion of cable sheath sometimes occurs in regions where there is an abrupt change in the character of the soil. This might have been predicted from laboratory studies which have shown potential differences of more than 0.3 volt between lead electrodes immersed in two different soil waters.

It is not uncommon for the sheathing of underground telephone cables to carry as much as 100 amperes of current derived from leaky power circuits. Under these conditions, on a full size cable there is an IR drop along the cable of about 0.1 volt per hundred feet which may create a large-scale galvanic cell provided there is a low-resistance path through the earth between two points on the cable at some distance apart. Precaution against corrosion in such a case consists in bonding the two points with a metallic conductor, thereby completing a metallic circuit and preventing current flowing from the sheath to earth.

The corrosion of cable sheath by acetic acid vapor occurs sometimes in creosoted wood conduit. It depends upon the maintenance of a suitably high concentration of hydrogen ions in the presence of oxygen and carbon dioxide and the formation of a non-protective film of basic lead carbonate. Early cases of cable sheath corrosion in creosoted wood ducts resulted from the use of wood creosote containing acetic acid. Recent extensive corrosion of this type on the Pacific Coast has been found to be due to the use of Douglas fir ducts incompletely creosoted. This wood is markedly more acidic than southern pine, which is used largely in other parts of the country for wood conduit, and moreover fir conduit is difficult to penetrate with creosote. The corrosive attack appears to have been stopped by neutralizing the acid with ammonia gas forced through the ducts in a mixture with air.

The most dangerous and most common kind of corrosion to which cables are subject is the ordinary electrolytic or stray current corrosion which may occur when the sheath becomes positive to earth. Here moisture conditions and soluble salts are of considerable importance since these affect the earth resistance and the anodic areas and hence influence the current densities at the point where current flows from the sheath to earth. Precautions against this type of corrosion consist in periodic electrolysis surveys, the bonding of cables to the negative returns of power circuits, and sometimes the shielding of the cable network against stray currents.

Finally there is cathodic or negative corrosion to which reference has already been made. This is characterized by the formation of red crystalline lead monoxide which crystallizes from saturated solutions of lime or alkali plumbites. Lead is readily dissolved by strong alkalies with the formation of plumbites which are stable only in solution. The alkalies

responsible for corrosion may be produced by the electrolysis of soluble lime or alkali salts. Sodium chloride or ordinary table salt is used sometimes to thaw out street car switches in winter and occasionally finds its way into cable ducts where it is converted into caustic soda at the surface of the cable sheath as a result of current flow from the earth to the sheath. This type of corrosion also occurs in newly manufactured concrete conduits owing to the presence of free lime in the concrete.

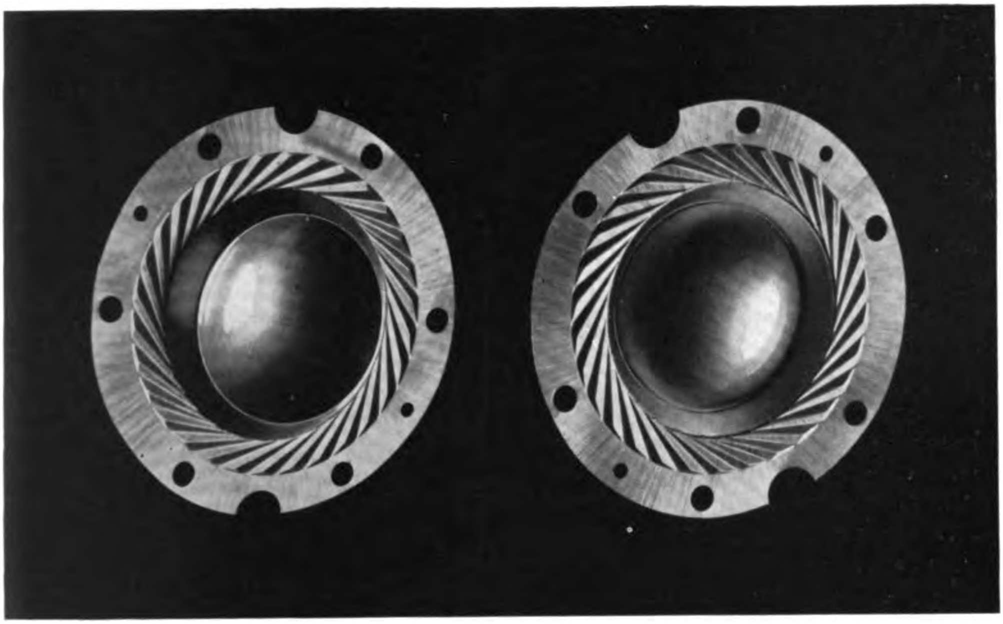
It might be inferred, from this summary of the mishaps which may befall a lead sheath, that underground cables are a rather vulnerable point in the Bell System plant. As a matter of fact, the losses of cable due to corrosion are relatively small, thanks largely to care in the selection of conduit material, and to the skill and vigilance of the Plant Departments' forces. But when it is recalled that the Bell System has in service some 55,000 miles of underground cable, containing nearly thirty-eight million miles of wire, it is evident that no pains are too great to find the causes and so prevent corrosion of the protecting lead sheath.

High-Strength Aluminum Alloys for Diaphragms

By W. J. FARMER
Apparatus Development Department

FOR the past ten years, aluminum alloys have to an increasing extent taken the place of steel, brass, bronze and other more common metals in many fields of industry. Used in the form of thin sheets, one group of the alloys has brought marked advantages to certain of the newer developments in telephone transmitters and receivers. There, used as diaphragms, they contribute prominently to high operating efficiency.

This group presents such a range of mechanical properties that those desired for almost any use can be secured by choice of an alloy of suitable composition, coupled with appropriate metallurgical treatment. Since strength, elongation and ductility can be controlled within wide limits, the necessary values in these respects can be secured in any cases but the most exacting. The greatest advantage, of course, is the low density, about a third that of steel. Another major advantage with most of the alloys, not otherwise found in nonferrous metals, is that parts can be increased in strength by heat treatment when they are in final manufactured form. Less important, manufacturing operations are facilitated by the low modulus of elasticity. It is about a third that of steel, so that the force needed for bending and other forming operations is about a third that which would be required



Formed diaphragm for a WE-555 Receiver, made of 17ST Alloy 0.002 *inch thick. It is used principally with sound-picture apparatus*

with steel parts of the same strength. The alloys are not immune to corrosion, but are much less subject to it than many of the materials which might be used in their stead. A quite different consideration makes them available for use in large quantity: the cost, although commonly considered high, is about the same as that of steel, when taken on the basis of volume rather than of weight. These facts, therefore, mean that there are available materials higher in ultimate tensile strength and in elastic limit than mild steel, with approximately one third the weight for a given part, and costing about the same per part.

Many different compositions are available, but discussion will be confined to the two alloys commonly used in thin sheet form for diaphragms. These are the 17S or duralumin alloy and the 3S alloy. They are known by these numbers in accordance with the code adopted by the principal supplier, wherein each alloy is identified by a number followed by the letter S. That code reveals the chemical composition only; the temper and metallurgical treatment are given by a supplementary code consisting of one or more letters. These symbols do not tell the complete history, but only the processes revealing the current condition. Annealing is represented by O, and cold-working by H. W represents heat-treating followed by quenching only, T those processes followed by aging, and RT the more common sequence of heat-treating and quenching followed successively by aging and cold-working. The material for a particular diaphragm may therefore be 17SO at one stage of manufacture, after it has been annealed to facilitate forming, and at the end, when it has been hardened for use, be 17ST.

Duralumin is made up of approximately 4% copper, 0.25% silicon,

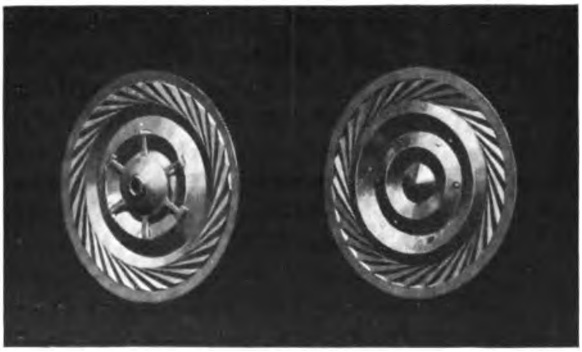
0.5% each of manganese and magnesium, and the remainder commercially pure aluminum. Although the total percentage of alloying ingredients is small, this material, whose density is very little higher than that of pure aluminum, can be brought by means of a tempering process to a tensile strength of 55,000 pounds per square inch with a substantial degree of ductility. The tensile strength may be raised by subsequent cold-working to at least 70,000 pounds per square inch; at the same time the property of ductility is almost entirely lost. Tempering may may be produced in various ways, but the usual method consists of heating the material to approximately 510° C., quenching it in water and allowing it to age at room temperature. Heating at this temperature for seven to ten minutes is usually sufficient for thin stock. The hardening proceeds very rapidly at first and then at a gradually diminishing rate until the maximum is reached at the end of five days. After heating and quenching, hardening may be carried out more quickly by maintaining the parts at 100°C. for a period of forty hours, a process known as artificial aging. When a part is to be made from heat-treated duralumin, there must be no delay between heat-



Diaphragm of handset transmitter; the material is 17ST Alloy

treating and forming else the material will become so hard that it may fail in the course of the forming operations.

For use in several pieces of apparatus it has been necessary to raise the ultimate tensile strength of the 17S alloy to 75,000 pounds per square inch, and in special cases to as much as 85,000-95,000 pounds. This was accomplished by reducing the cross-sectional area about 90% through operations known as cold-working — swaging, drawing, rolling, and other cold processes. Material so handled, characterized by high tensile strength and elastic limit and by very small elongation, is specified as 17SRT. For other operations, annealed material is reduced 80% in thickness by similar cold operations. The material thus produced, 17SH, has an ultimate tensile strength of 45,000 pounds per square inch and negligibly small elongation.



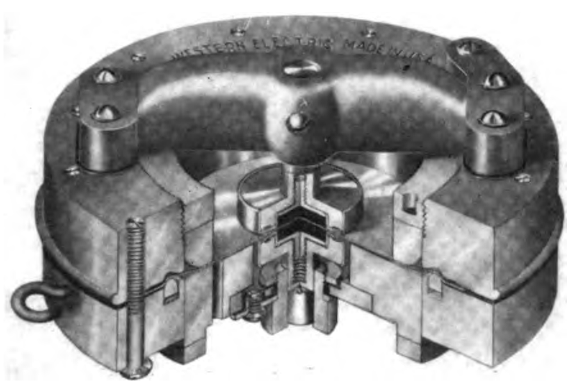
Reproducer for an Orthophonic talking machine, of 3SH Alloy; the spider is of hard commercially pure aluminum 0.014 *inch thick*

The other alloy extensively used, 3S, consists of commercially pure aluminum to which has been added approximately 1¼% manganese. In the annealed state it is about 25% stronger than annealed pure aluminum, and of slightly lower elongation. By cold-working its tensile strength may be brought up to about three times that of annealed aluminum, with a high ratio of elastic limit to ultimate strength. This alloy is therefore an extremely useful material in cases where severe forming is required. It does not, however, respond to heat treatment.

Both of these alloys may be rendered soft and ductile by annealing at approximately 343°C. at any time in the manufacture of parts if the hardness was caused by manufacturing operations carried out on formerly annealed material. Where the hardened condition was produced by heat treatment, as may be the case with duralumin, annealing requires heating for a longer time and at a higher temperature, followed by very slow cooling. Some of the deeply formed diaphragms are annealed a number of times in the course of production to remove the hardness resulting from the stresses of the forming operations.

The alloys are received at the Hawthorne plant of the Western Electric company from the manufacturer in coils 0.020 inch thick. There they are rolled into ribbons of the thickness wanted, and generally just wide enough to make the blank for a single diaphragm. In all cases the material is buffed as it comes from the rolls. By this operation the resistance to corrosion is raised materially by the highly polished surface obtained. The thinnest material in use at present is a duralumin alloy for spacing washers of condenser transmitters; its thickness is only 0.00075 inch, about a sixth that of the paper on which the RECORD is printed. The most common thickness is 0.003 inch, and the thickest material commonly used is 0.005 inch.

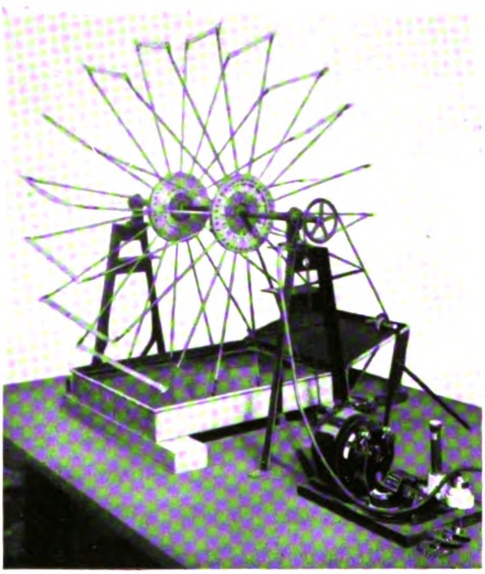
Aluminum and its alloys are generally considered resistant to corrosion, and for thicknesses greater than 0.020 inch that is the case. In several pieces of apparatus the alloys are used in sheets 0.001 inch to 0.003 inch thick; obviously a very small degree of corrosion would be enough to reduce the cross-section of those parts by an extent sufficient to cause failure. Corrosion has therefore been studied intensively on pieces of apparatus and on the sheet stock as well. Since interest was mainly in objects 0.0017 inch and 0.003 inch thick, the tests were carried out on tensile samples cut from materials of these thicknesses. Several methods of corroding the alloys artificially have been



387-W Transmitter, for broadcasting. The diaphragm, which passes between the two carbon buttons, is a sheet of 17*SRT Alloy,* 0.0017 *inch thick, stretched by the clamping ring*

tried, principally spraying with a salt solution, outdoor exposure tests on the roof and intermittent immersion in corroding solutions.

Our most dependable corrosion test makes use of a device resembling, on a small scale, the Ferris wheels of



Ferris wheel for corroding the aluminum alloys artificially

amusement parks. The device was developed by the Chemical Research Department. The tensile samples after measuring and cleaning are clamped into position at the circumference of the wheel, which is then rotated slowly and evenly for eighteen hours. They dip successively into the corroding solution at the bottom of each revolution and then drain and dry while completing the cycle; the corrosion occurs during drying. At the end of the corroding process the samples are removed and are broken in a tensile testing machine. Uncorroded samples from the same stock are also broken, for comparison. Protective finishes are appraised with the same piece of testing apparatus; coated and unprotected samples are exposed together, and then the ultimate tensile strengths of both groups are determined.

As rated by this machine chemically pure aluminum was highest in resistance to corrosion, and commercially pure aluminum second. Then followed a number of alloys, depending for their order on the treatment they had undergone as well as on their composition. The corrosion resistance is also determined in part by the surface. As might be expected, when it is smooth and highly polished it affords a considerably smaller opportunity for corrosion to start than does the somewhat rough gray surface commonly seen on aluminum cooking utensils.

Choice of the alloy for a particular use cannot be made entirely on the basis of corrosion tests, of course; mechanical requirements at times are such that a particular alloy and temper must be used regardless of its low resistance to corrosion. For such cases the problem of increasing the resistance to corrosion, in order to insure that the part will last through the life of the apparatus, has been studied in the Chemical Laboratories. Either one or two coats of varnish, sprayed onto a finished part, affords satisfactory protection but adds appreciably to the weight. Thin Bakelite varnish is also satisfactory for alloys whose mechanical properties are not changed by the baking operation.

An interesting effort to combine moderate mechanical strength with maximum resistance to corrosion is the Alclad alloy, developed and manufactured by the Aluminum Company of America. Sheets are made by roll-

ing a slab made of duralumin or one of the other alloys in the center and aluminum on the outside. Thicknesses of the layers are chosen to give a finished sheet of duralumin 0.002 inch thick covered on each side with 0.0005 inch of pure aluminum. Users can secure Alclad 3S, Alclad 17S, or sheets made with other alloys in the center, to suit their needs. Particular care is needed, however, in heat-treating Alclad sheets, since there is a tendency, while the material is hot, for the copper to diffuse from the center layer into the aluminum and so to reduce the corrosion resistance of the protective layers. The material presents interesting possibilities where there is danger of corrosion and where the necessity for lightness makes it inadvisable to increase the weight with a protective varnish.

Although aluminum and its alloys are used elsewhere in the telephone plant, these high strength alloys in sheet form find their most important use in the solution of a basic problem, the transfer of vibrations between the air and the vibrating member of a transmitter or receiver. For the most efficient and faithful transfer of energy the difference in impedance of the two media must be reduced to a minimum and for that end the moment of inertia of the diaphragm, and hence its mass, must be made as low as possible. In high-quality transmitters, where the flatness of the frequency-response curve comes in part from the fact that the range of resonance of the diaphragms is brought near the upper end of the voice frequencies by the tension under which the diaphragms are held, the material must be of minimum density, yet strong enough to withstand stretching to the desired tension. Likewise in the diaphragms of dynamic receivers stiffness is as much an essential as light weight, and strength is needed on account of the handling during assembly. For these uses, and for many others, the sheet alloys by their combination of high strength and light weight, and by their ability to withstand difficult manufacturing processes, make possible results that could otherwise not be attained.

The Edison Medal

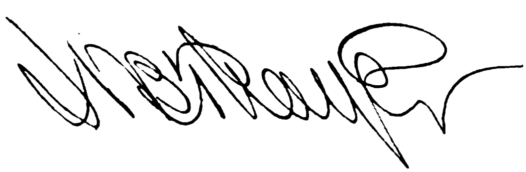
To Dr. Jewett has been awarded the Edison Medal for 1928, in recognition of his "contributions to electrical communication". This medal is awarded annually by a committee of twenty-four members of the A. I. E. E., for "meritorious achievement in electrical science, electrical engineering, or the electrical arts". Among previous Edison Medallists are Alexander Graham Bell, John J. Carty and Michael I. Pupin.



E. P. CLIFFORD, 1875-1928

WHEN I think of the decade in the history of the Western Electric Company beginning about 1895, I think of a period of intense and continuous activity. We were going through a revolution. We had been accustomed to growth but the kind of growth in which building factories becomes a routine was just beginning. We were finding that our methods in the shop and office had to be reconstructed to adjust them to the faster pace and that our organization had to be modified and expanded. But we had men.

Now, thirty years after, the specific difficulties do not linger in my mind. The picture I see is of a group of eager, resourceful, loyal, young men grappling the difficulties with the enthusiasm of a foot-ball squad going into the field. One of those young men, and not the least, was our friend Mr. Clifford. When you read the story of his progress in the Company, it does not mean stepping from one established, well organized position on to other better and similarly organized positions. It meant reconstructing a department and getting it to run smoothly and then repeating the process in a larger field. So, when during the war, the Laboratory found itself, almost over night, a commercial manufacturing concern, making in large quantities the apparatus needed by the Army and Navy, but without the necessary commercial and manufacturing organization or methods, it was Mr. Clifford who went into the Laboratory organization to supply what was lacking. There was no question then as to whether or not it was a promotion. There was his kind of a job to be done and he did it and he made it a promotion. We shall all remember him with great affection and respect. I shall also remember him as one of those who helped over the hard places.



Counteracting Dialing Errors in the Step-by-Step System

By T. L. DIMOND
Systems Development Department

IN dial systems it is necessary not only to provide means by which a subscriber may be connected with whatever party he is calling when he dials the correct number, but also to make arrangements for taking care of incorrect dialing as far as possible. Among the dialing errors which can be counteracted are those due to preliminary pulses, those which route calls to vacant selector levels, and those which direct calls to lines unequipped or out of service. These will be considered in the order named.

Occasionally it happens that a subscriber unintentionally sends what is known in dial parlance as a preliminary pulse before he dials the number of the subscriber whom he wishes to call. This preliminary pulse is generally caused by an accidental jiggling of the switchhook before the number is dialed. When the switchhook is momentarily pushed down after having been released, it opens and then short-circuits the two wires of the line as though the digit 1 had been dialed. This causes the selector in the central office to take one vertical step and prepare the circuits for the next digit.

If nothing were done to retrieve this error, upon completion of dialing the subscriber would obtain a number beginning with 1 and completed by all the digits except the last of the number of the called subscriber. In an exchange area using four-digit numbers, for instance, if a subscriber should desire to call the number 9284 and in preparing to dial send a preliminary pulse, he would in effect dial the number 19284, and would obtain the number 1928. The digit 4 would produce no result, since the circuits are so arranged that extra digits are ineffective.

In order to show how a step-by-step dial office is arranged to take care of this condition, it will be of aid to review briefly the progress of a correctly dialed call through such an office. Figure 1 gives a schematic showing the manner in which the ordinary line finders, selectors, and connectors are arranged in a four-digit step-by-step office. When a calling subscriber takes the receiver from its hook, a line finder immediately steps vertically until it reaches the level on which the terminals of the calling subscriber's line appear, and then hunts across the level until these terminals are found. The first selector, which is permanently connected to the line finder, then sends back a tone to the subscriber as a signal for him to dial. In returning to normal on the first digit the dial opens and closes the line loop, causing the first selector to step vertically one step each time the line is opened. As a concrete example let it be assumed that the number 9284 is dialed. When the number 9 is dialed, the first selector

takes nine vertical steps and then hunts across the ninth level for an idle trunk leading to a second selector. On the next digit, 2, the second selector takes two vertical steps and hunts across the second level for an idle trunk to a connector. This connector has been chosen by the first two digits as the one having the terminals of the called subscriber's line appearing among the terminals accessible to it. The calling subscriber next dials 8. The connector steps vertically just as does a selector, but since it is now required to seize the terminals of a particular line on the eighth level rather than to choose an idle trunk from a group, it does not hunt over this level. As the subscriber dials the last digit, 4, the connector takes four steps in a rotary direction, seizes the line, rings on it, and connects the two subscribers together when the called subscriber answers. It may be seen that if the subscriber had given a preliminary pulse, in effect dialing the digit 1, the call would have been routed to a connector which did not contain the terminals of the called subscriber's line.

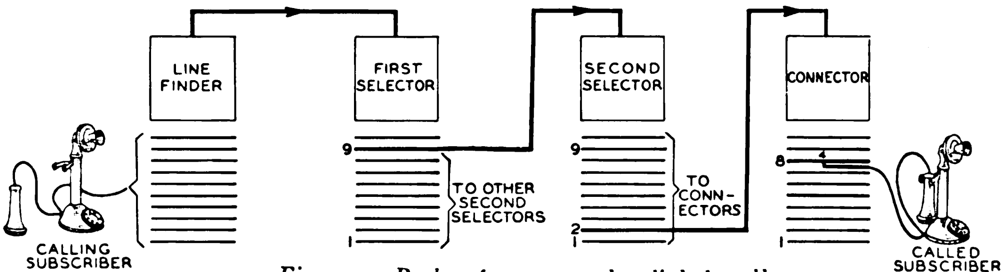


Fig. 1—*Path of a correctly dialed call*

To prevent errors of this sort the arrangement shown in Figure 2 is used. The trunks from the first level of the first selectors, instead of being run to regular second selectors, are terminated in special second selectors which are in no way different from the regular second selectors insofar as circuit operation is concerned. However, the trunks from all levels of the special second selectors except the first are multipled to the trunks of corresponding levels of the first selectors. If the calling subscriber dials 9284 preceded by a preliminary pulse, or in other words dials 19284, the first selector will take one vertical step and find an idle trunk to a special second selector. When the digit 9 is dialed, the special second selector will step vertically nine levels and find an idle trunk. In effect, however, the ninth level of the special second selector is the same as the ninth level of the first selector because the trunks from these levels are multipled. Hence the call is now at the same point as it would have been if the preliminary pulse had been omitted. Further digits will direct it through the third selectors and the connectors to the same line as that to which the correctly dialed number would have routed it; the preliminary pulse has therefore been absorbed.

It will be noted that the employment of the first level of the first selector in caring for preliminary pulses prevents the assignment of subscribers' numbers beginning with the digit 1. However, it is desirable in any event to set apart one level of either the first or second selectors in a four digit office for calls to the in-

formation desk, the toll switchboard, the trouble clerk, and the reverting call selectors. In the interests of economy one level, the first of the selectors, is used both in counteracting preliminary pulses, and in routing the special calls just mentioned.

In order that the first level may comparatively small number of special second and auxiliary third selectors. Selectors equivalent in function to the special third selectors would be needed for the special calls in any case, even if no effort were made to compensate for the preliminary pulses.

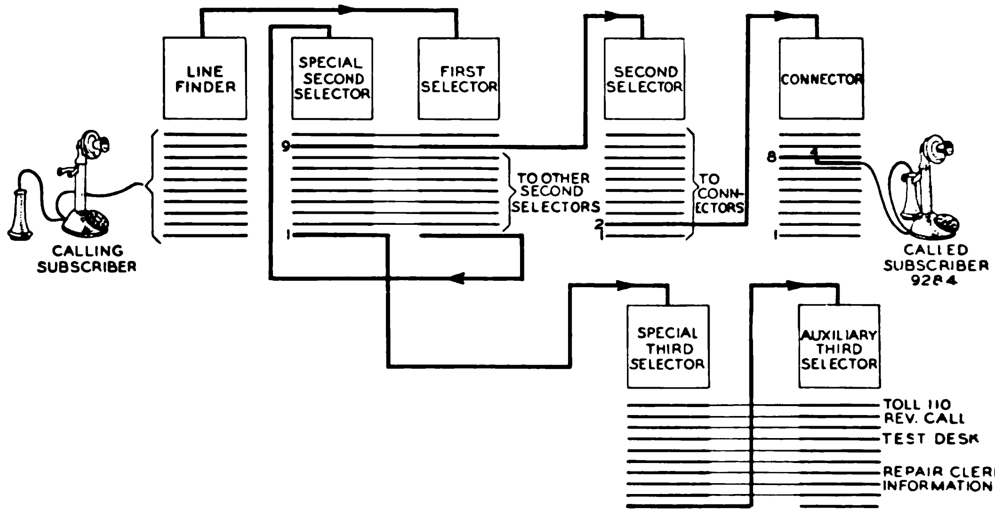


Fig. 2—Path of a call preceded by a preliminary pulse, showing the supplementary switches for special conditions

also be used for the special calls, trunks from the first level of the special second selectors are carried to special third selectors, from whose levels, except the first, trunks go to jacks and other terminals for completing the calls. From the first level, trunks run to auxiliary third selectors, whose banks are multipled with those of the special third selectors to care for preliminary pulses on special calls. With this arrangement, subscribers are able to make toll, reverting and other special calls by dialing the number 11 followed by another digit. It may be seen from Figure 2 that the only additional apparatus required by this method of counteracting preliminary pulses is a

The handling of service and other special calls may be seen by tracing calls with and without a preliminary pulse to the toll switchboard, to which the number 110 is usually assigned. Without the preliminary pulse the call will be directed from the line-finder to the first level of the first selectors, to the first level of the special second selectors, to the tenth level of the special third selectors, and thence to the toll operator. When preceded by a preliminary pulse, the call will advance from the line finder to the first level of the first selectors, to the first level of the special second selectors, to the first level of the special third selectors, and then to the tenth level of the auxiliary third se-

lectors. Since this level is multipled to the tenth level of the special third selectors, calls routed to the tenth level of either group of selectors will go to the toll operator.

Having considered the method by which calls preceded by preliminary pulses are routed to their proper destination let us turn our attention to calls which are routed to vacant selector levels. The zero (tenth) level of the first selector is used for calls to the operator, and the first level is used as just described. Unless the central-office unit is fully equipped for the 8000 lines possible with the remaining levels no numbers will be assigned in certain of the hundreds and possibly in certain of the thousands, and the corresponding levels of the second or first selectors will be vacant. If a call were directed by the subscriber to one of these vacant levels, its progress would be immediately stopped, and, if no provision were made to care for such a condition, the subscriber would receive no indication to tell him what is wrong. Consequently two different methods of handling such calls have been developed, the method to be used for a particular selector level depending upon whether the calls which must be handled from this level are due to errors in the current directory or to subscribers' errors.

When there is a directory error involving a vacant selector level, all of the trunks of the level are made artificially busy except those which are carried through intercepting trunk circuits to jacks in front of an operator. If a selector starts hunting over a vacant level equipped in this manner, it will hunt over the busy trunks and seize one of the idle intercepting trunks, causing a lamp associated with the jack to light in front of the operator. The operator answers the call, inquires the number dialed and gives the calling subscriber the correct number.

Unless a directory error is involved, the calls which come to a vacant selector level are nearly always chargeable to subscribers' errors in dialing. Such levels have all trunks made busy except those which are connected to tone trunk circuits which, when seized by a selector, return a modified busy tone to the subscriber. The modified busy tone is the same as the ordinary tone, except that every third spurt is omitted. Since the subscriber has instructions that such a tone is received only because an incorrect number has been dialed, he has been informed that he has made some error and may act accordingly.

With either of these methods, the necessary number of intercepting trunk circuits or tone trunks is reduced by multipling the trunks from the several selector levels to the same intercepting trunk or tone trunk. When any one of the trunks becomes busy, it will cause all of the other trunks in the same multiple to test busy. Hence the number of selector level trunks which may be connected to the same intercepting or tone trunk is limited by traffic conditions.

Calls to unequipped or out-of-service lines are taken care of by a method similar to that used in caring for calls to selector levels involved in directory errors. Such calls may not in all cases be made on account of errors in dialing. For instance, the number of a subscriber may have been changed between the periods of directory changes. He is, of course, entitled to receive calls directed to his

number as published in the telephone directory. Likewise a subscriber calling a published number can reasonably expect to have the call transferred to a more recent number, or to be informed of any condition preventing completion of the call. Accordingly, the terminals of lines involved in number changes, discontinuation of service and similar circumstances are carried from the connector multiple to trunk circuits which terminate in jacks in front of an operator. When a call is directed by a subscriber's dial to a set of terminals equipped in this way, a lamp associated with the trunk jack is lighted in front of the operator, who intercepts the call, inquires the number wanted, and explains the condition of the called line.

The number of trunks required from the unequipped connector terminals is reduced by multipling several connector terminals to the same trunk. Here again, the number which may be multipled to the same trunk is limited by traffic conditions.

H. D. Arnold's Remarks upon Receiving The John Scott Medal

I thank you for this award; and I wish to express my appreciation of the honor which it conveys. It is interesting to recall that it was here, in the City of Philadelphia, the vacuum tube mentioned in the citation found its first commercial telephone use. In September, 1913 *vacuum tubes were installed here to relay conversations through the telephone cable between New York and Washington, and from that small beginning has come its present widespread use. In accepting this present recognition, Mr. Secretary, I feel doubly honored; I am proud to stand as the representative of that large body of scientists and engineers whose efforts have brought this development to its present state; and I am profoundly grateful to Fortune for allowing me to have a part in the early beginning of this important phase of telephone communication.*

Operators' Transmitters and Receivers

By H. I. BEARDSLEY
Apparatus Development Department

WITH the institution of the first telephone central office there arose a need for transmitters and receivers which were suitably arranged for operators' use. The requirements for these instruments in central office service were so different from those of use at the homes and offices of subscribers that instruments for the two types of service necessarily were developed along separate lines. The development of operators' instruments has profited by the fundamental studies made upon instruments in general, but at the same time has involved differentiations in physical form to facilitate the work of the operators in handling subscribers' calls.

Succeeding the original "butter stamp" hand telephone the instrument, used by the operators in 1878, was a device serving both as a transmitter and receiver. In appearance slightly resembling a desk stand receiver of today, it is shown in use in Figure 1 of the historical pictures. Developed by Bell and known therefore as Bell's hand telephone, it was a single-pole, permanent magnet instrument. The magnet was a straight bar mounted at right angles to the diaphragm, and bore a coil placed around a soft-iron extension at the end. The earliest of these instruments were enclosed in cases of wood. When one was used as a transmitter, sound waves impinging upon the diaphragm caused it to vibrate and so varied the magnetic field, inducing in the coil varying currents which were electric counterparts of the sound waves. When this instrument was used as a receiver the incoming voice current, by its variations, changed the magnetic field of the coil through which it flowed, thereby vibrating the diaphragm and producing a close approximation to the original sounds.

The following year, 1879, there came the instrument shown in Figure 2. The transmitter and receiver units were separate, but were arranged to be held in one hand. The transmitter, of the type developed by Edison, was changed in function; it no longer generated the voice-current, but by changing its resistance in response to the sound waves it varied the current supplied by a battery. A toothed metal ring in contact with the back of the diaphragm pressed against the front electrode, a hard carbon disc. By that construction pressure of the disc against the back electrode, a disc of soft carbon, was varied, and the current was changed correspondingly. The receiver operated on the same principle as the older instrument and was made up of equivalent parts. Instead of being at right angles to the diaphragm however the bar magnet formed the handle on which the transmitter and receiver were mounted.

That same year there was introduced the operator's set of Figure 3, with the transmitter and receiver en-

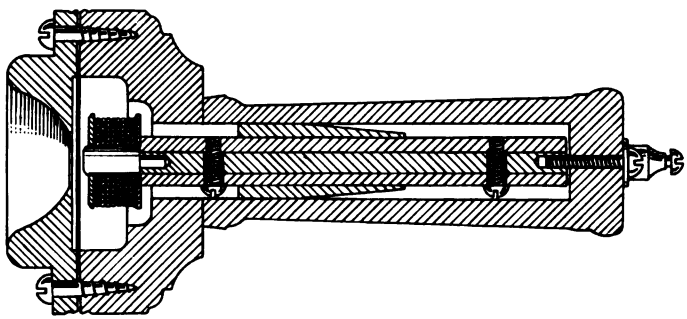


1, *Bell's hand telephone in use as a transmitter. The same instrument acts as a receiver with incoming voice-currents;* 2, *Transmitter and receiver were mounted at opposite ends of a bar magnet in this operator's handset of* 1879; 3, *An early Blake transmitter and associated receiver, mounted to leave one of the operator's hands free;* 4, *Instruments the same as those of Figure* 3, *supported in a "Gilliland harness" to free both hands;* 5, *Another mounting arrangement keeping both hands free*



6, *A White Transmitter, and a Richards receiver mounted on a headband. The set was brought out in* 1891; 7, *Another supported transmitter, used with a completely enclosed receiver. Compactness of the receiver was obtained by use of a spiral magnet;* 8, *In this set the transmitter is essentially the same as those of today, and the receiver is of bipolar type, with a horseshoe magnet;* 9, *Today's set, with receiver held by a swivel yoke to a wire headband*

tirely separate. The transmitter derived its name from Francis Blake, Jr., who carried out the original development on which it was based; its operation was by variation in resistance at the contact between the disc of hard carbon and a metal ball supported against the back of the diaphragm by a light spring. A heavier flat spring supporting the disc kept it pressed against the ball, so that vibrations of the diaphragm produced pressure differences at the contact area. To secure the proper range of pressures, adjustment was provided by supporting the spring upon a hinge-like member whose position was controlled by a screw. The transmitter was enclosed in a wooden box having an opening in front of the diaphragm, and was supported before the operator by a vertical rod. The receiver, held in the operator's hand during use, was unchanged in principle, but resembled in appearance the desk stand receivers with external binding-posts; the case was of hard rubber.



Section of Bell's hand telephone which was used as both transmitter and receiver

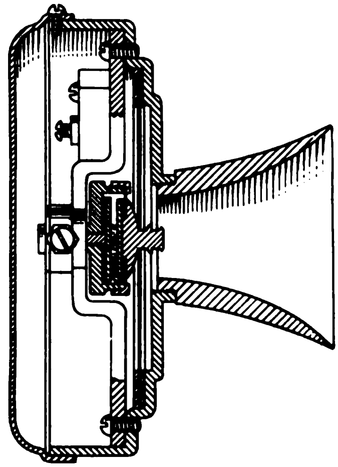
The next year the same instruments were mounted in a structure which freed both the operator's hands. This was the "Gilliland Harness" of Figure 4, an adjustable framework resting on her shoulders and strapped around her waist, supporting the transmitter a short distance in front of her mouth and the receiver at her ear. On account of its weight, almost 6½ pounds when fitted with instruments, this structure was not put into general use. Figure 5 shows another mounting arrangement brought out that year which held the transmitter at a convenient position by a vertical rod, and by a horizontal bracket held the receiver near the operator's ear. Though requiring that she hold her head in a particular position for speaking or listening, it was a noteworthy advance over the harness from the standpoint of comfort.

An important change in design was embodied in operator's transmitters produced in 1888. In accordance with a somewhat earlier development, both electrodes were of carbon and the space between was filled with carbon granules. Change in resistance with vibration of the diaphragm came from variations in pressure at the large number of contact surfaces between the granules, rather than at a single contact surface as before. In 1890 came the "solid back" design of Anthony C. White, not incorporated in operator's instruments however until the following year. The rear electrode was no longer mounted on a spring, but was attached rigidly through a small intermediate part to the back of the case, and the front electrode was held by a metal stud which passed through and clamped the center of the diaphragm. In 1891

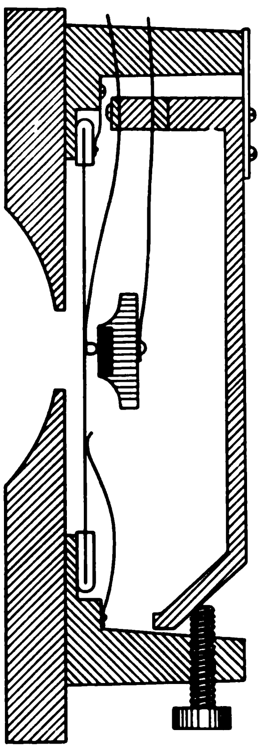
a similar transmitter was made a part of the set shown in Figure 6. It is of interest to note that the mouthpece used resembles that of today's desk stands in size and shape.

The receiver used was designed in 1884 by W. L. Richards, now Consulting Historian of the Laboratories. It was one of the earliest of the thin or watch-case type, suitable for use with a headband. Essential parts corresponded to those of previous designs, but compactness was secured by placing the bar magnet on the outside of the receiver case to form the bracket by which the headband was attached. An extension, consisting of a soft-iron core at right angles to the end of the magnet, ran through the center of the coil inside the case. Small screws near the middle of the bar magnet fastened the receiver to a headband sufficiently large in area to distribute the weight well over the operator's head.

Another adaptation of an independently supported transmitter and



The carbon granules of the White solid back transmitter separating the two carbon discs, gave a large number of contact surfaces for variation in resistance



In Blake's transmitter a carbon disc was pressed by a flat spring against a contact point touching the diaphragm

headband receiver, that of Figure 7, was put into use about the same time. The transmitter was the same in internal structure as that just described, but was supported by a bracket extending from the switchboard. Though still of single-pole construction the receiver was made more compact by the use of a laminated, curved magnet of the so-called spiral type, enclosed within the case. Attachment to the headband was by a thumb nut.

About 1900 came the transmitter which is similar in form to that now used by operators throughout the Bell System. It was mounted on a breastplate supported and held in place by a tape extending around the operator's neck. Adjustment of the tape and movement of the mouthpiece in its ball and socket mounting bring the

opening directly in front of the operator's mouth, and cleaning is facilitated by the ease with which the mouthpiece can be removed. The receiver used with this transmitter was of bipolar type, and a horseshoe magnet was substituted for the spiral magnet. Transmitter and receiver are shown in Figure 8.

The operator's set of today, shown in Figure 9, includes a transmitter similar in form to that just described but incorporating certain important changes, such as an improved carbon button, which make for better operation. A bipolar receiver with horseshoe magnet is used, but it is more efficient than the previous type, and its method of mounting is changed. On the outer periphery of the case are two small lugs, 180 degrees apart, with a hole in each for attachment of the headband. The band is made from a loop spring whose ends are clamped in a bracket; to the bracket is attached a swivel yoke with points for engaging the lugs. By the rotation and the free movement introduced, closer fitting is secured and extraneous noises are thereby excluded. These instruments, as is apparent, signalize a notable improvement over the early types of operators' sets, and embody the necessary electrical functions in a form which facilitates greatly the speedy completion of calls.

An Opener of Ways

Edward Preston Clifford, administrative officer of the Bell Telephone Laboratories, whose untimely death was recorded in Tuesday's newspapers, was not a scientific man. Yet the death of few New Yorkers could leave a wider gap in the human machinery of scientific research or one more difficult to fill. It was Mr. Clifford's lifework to help on other people's jobs; to hold an important place in the great army of those who smooth the pathway of science along which other men advance to more obvious renown. . . . For the notable accomplishments of his more strictly scientific colleagues Mr. Clifford and the skilled but unobtrusive administrators whom he had gathered deserve no small share of the praise.

—From an editorial in the Herald-Tribune of December 19, 1928

News Notes

Dr. Jewett was a member of the Advisory Board of The Second International Conference on Bituminous Coal held at Pittsburgh from November 19 to November 24, and presided over the morning session of the Conference on November 21. He was also a delegate to represent the National Academy of Sciences.

On November 23, Dr. Jewett attended the ceremonies at the inauguration of Harvey Nathaniel Davis as President of The Stevens Institute of Technology. On this occasion he also represented The University of Chicago, attending a dinner in honor of the delegates at the Hotel Astor on the evening of November 22.

Dr. Jewett gave a short talk before the Transmission Conference which met on November 16 at 195 Broadway.

At the December 3 meeting of the Colloquium, C. H. Prescott, Jr. spoke on "Chemical Equilibria at Incandescent Temperatures". R. V. L. Hartley spoke on "A Wave Mechanism of Quantum Phenomena" on December 17, prior to his presentation of a paper on that subject at the Christmas meeting of the American Physical Society.

There are now available for members of the Laboratories sets of personal financial records in booklet form. These records supplement the A. T. & T. income and expense record which has been available to members of the organization for some years. They are especially intended for those who do not keep a detailed expense account, but who wish to determine their financial status at intervals. Copies of these records may be obtained by applying to the Employee Service Department, Section 1-H, Extension 435.

Apparatus Development

H. Van Deusen, J. R. Townsend and C. H. Greenall were at Hawthorne during the week of November 19 in connection with the formulation of specifications for non-ferrous sheet and rod stock.

J. R. Townsend presented a paper on telephone apparatus springs before the Annual Meeting of the American Society of Mechanical Engineers in New York on December 6.

W. T. Pritchard visited "Marine" central office in Atlantic City to make studies of burnishing tools for step-by-step switches.

J. N. Reynolds was at Hawthorne during the week of November 12 in connection with new dial apparatus developments.

J. W. Beyer attended a meeting of the High Temperature and Electrical Resistance Alloys Committee of the American Society for Testing Materials at the Bureau of Standards in Washington.

F. F. Lucas spoke on "Microscopic Structure of Metallic Alloys" on December 28 before the American Association for the Advancement of Science at the Museum of Natural History, in this city.

E. W. Gent visited Hawthorne in connection with the production of a modulator unit to be used in equipment for a news reel camera.

R. NORDENSWAN was at Hawthorne in regard to the manufacture of a new loud speaker.

N. BISHOP recently supervised the conversion to provide crystal control and increased modulation in the five-kilowatt broadcasting equipment of the Churchill Evangelistic Association, now known as the Buffalo Broadcasting Corporation. He performed the same service for the Bankers Life Company of Des Moines; the Stromberg-Carlson Telephone Manufacturing Company of Rochester, and the one-kilowatt equipment of the Woodmen of the World at Omaha. He then inspected the five-kilowatt station of the National Life and Accident Insurance Company at Nashville, Tennessee.

B. R. COLE recently made a survey for Memphis Commercial Appeal, Incorporated, at Memphis, Tennessee, which recently purchased a one-kilowatt, crystal-controlled broadcasting equipment.

J. C. HERBER supervised the conversion to crystal control of the five-kilowatt equipments of the Moody Bible Institute and Sears, Roebuck and Company of Chicago, and the Consolidated Gas, Electric Light and Power Company of Baltimore; also the one-kilowatt equipments of Larus and Brother Company, Richmond, Virginia and the Detroit News and the Milwaukee Journal.

F. E. NIMMCKE supervised the conversion to crystal control of the one-kilowatt broadcasting equipments of the Universal Broadcasting Company of Philadelphia and the Peoples Pulpit Association at Rossville, Staten Island.

H. S. PRICE made surveys for the one-kilowatt equipment purchased by the Puget Sound Broadcasting Company, Seattle, and the five-kilowatt equipment purchased by the Southwestern Sales Corporation of Tulsa. En route he inspected the one-kilowatt station of Louis Wasmer, Inc. at Spokane, and visited Fort Worth to confer on the relocation of the one-kilowatt equipment taken over from the Searchlight Publishing Company by the Texas Air Transport Broadcasting Company.

W. L. TIERNEY has completed the installations of a one-kilowatt equipment for the Oregon State Agriculture College at Corvallis, Oregon, and a five-kilowatt equipment at Sherman Oaks, California, for the Western Broadcasting Company. He also made a survey for the five-kilowatt equipment purchased by Hale Brothers, San Francisco, and supervised the crystal control conversions of the one-kilowatt equipments of Don Lee, Incorporated, at Los Angeles and San Francisco, and of the Fisher Blend Station at Seattle, Warner Brothers at Los Angeles, and Nichols and Warinner at Long Beach, California.

O. W. TOWNER supervised the conversion to crystal control of the five-kilowatt equipment of the Voice of St. Louis, Inc., and the one-kilowatt equipment of the Jenny Wren Company, Lawrence, Kansas, the Gurney Seed Company of Yankton, South Dakota, and the Kansas City Star.

R. M. PEASE has, during the past few months, assisted S. P. Grace in demonstrations given in connection with Mr. Grace's talks. He was present at the latter's lectures before the Rotary Club of Brooklyn on December 6; Sigma Xi Chapter of McGill University at Montreal on December 19, and before the employees of The Bell Telephone Company of Canada at Montreal on December 20. He also aided in setting up the equipment used by John Mills in his Tor-

onto lectures, December 13 and 14.

Systems Development

J. R. P. Goller and R. L. Lunsford inspected the new unit type toll repeater power installation at Greensboro, North Carolina. This installation is part of the Washington-Atlanta Cable.

J. R. Stone and C. Borgmann tested and inspected high speed centrifugal exhauster equipment for pneumatic tube installations in West Lynn, Massachusetts.

V. T. Callahan tested a BA gasoline engine set, recently installed in Savannah, Georgia.

C. E. Boman spent several days in Chicago in connection with problems of machine switching equipment.

I. W. Brown visited Milwaukee and Detroit, preliminary to the installation of new toll facilities there.

J. H. Sole visited the General Electric Company at Pittsfield, Massachusetts, to confer on the development of a transformer to provide current for lamp signals in toll boards.

J. Irish visited Chicago in connection with circuit drawings and practices.

D. M. Terry discussed the 1-A carrier pilot channel equipment with members of the staff at Hawthorne.

J. P. Kinzer visited Morristown, New Jersey, and Allentown, Reading and Harrisburg, Pennsylvania, in connection with modifications of 2-wire repeaters in cable circuits.

A. E. Bachelet conducted tests of half-ampere ballast lamps used with 2- and 4-wire repeaters at the A. T. & T. repeater station at Juliet, Illinois.

J. A. Krecek spent several weeks in El Paso, Texas, testing 2-wire echo suppressors to be used in conjunction with picture transmission circuits.

E. P. Bancroft is engaged in the installation of telephone and carrier telegraph equipment for the Canadian Pacific Railways.

C. B. Sutliff recently assisted with the demonstration of an oscillograph before the American Optical Society in Washington.

Research

J. M. Finch and A. C. Walker were present at a meeting of the American Society for Testing Materials at Philadelphia.

H. H. Lowry attended a meeting of the Committee on Insulation Materials of the National Research Council at Johns Hopkins University in Baltimore.

A. R. Kemp visited the plant of the General Electric Company at Bridgeport on November 20 to confer on the development of rubber covered wire and cable.

J. H. Ingmanson viewed a demonstration of the impregnation of jute for the protection of lead cable sheath, at the Schlichter Jute Cordage Company, Philadelphia.

W. A. Marrison demonstrated oscillographs of polar and motion-picture types at the apparatus exhibit held in connection with the meeting of the Optical Society of America in Washington.

C. H. Haynes conferred with representatives of the Standard Machine Company, Providence, on the construction of special rolls for the manufacture of platinum filament.

C. A. Kotterman made an inspection trip in connection with the Laboratories' exhibit at the National Academy of Sciences, Washington.

T. C. Fry spoke on the use of continued fractions in the design of electrical networks before the American

Mathematical Society in Cincinnati.

IN "SCIENCE" for November 16, K. K. Darrow describes and correlates the results of recent experiments on the scattering of quanta with diminution of associated frequency. These phenomena are associated with the Raman effect.

J. M. EGLIN described a direct current amplifier for measuring small currents before a meeting of the American Physical Society at Minneapolis on November 30.

C. J. DAVISSON AND L. H. GERMER presented a paper on a test of the state of polarization of reflected electron waves before the same Society on December 1.

J. C. SCHELLING addressed the Physics Seminar of Cornell University on November 19 on "Some Theoretical and Experimental Phases of Radio Transmission."

E. F. KINGSBURY spoke on television before the Men's Club of Rutherford on December 14.

INSPECTION ENGINEERING

E. G. D. PATERSON visited the Highway Trailer Company at Edgerton, Wisconsin, on November 12, in connection with studies of inspection methods for automotive equipment.

W. A. BOYD attended a regular survey conference on step-by-step apparatus at Hawthorne.

H. F. KORTHEUER AND H. C. CUNNINGHAM attended a regular survey conference in connection with carrier equipment at Kearny.

G. D. EDWARDS visited Cleveland, Chicago and Boston during the latter part of November and early December, in connection with Field Inspection Engineering work. While in Boston Mr. Edwards attended the decennial anniversary celebration of the "Binaural Sons of the C", an organization composed of representatives of the United States Navy Department, the Submarine Signal Company, the General Electric Company, the Western Electric Company and of various educational institutions which cooperated during the World War in developing methods and apparatus for the detection and location of enemy submarines.

W. A. SHEWHART visited Philadelphia during the latter part of October to attend conferences held by the American Society for Steel Treating and the American Society for Testing Materials.

OUTSIDE PLANT DEVELOPMENT

A. W. DRING investigated several special cable terminal installations in Philadelphia on November 13.

J. M. HARDESTY made tests of reinforced concrete poles in Charlotte, North Carolina.

R. C. EGGLESTON investigated preservative treatments and made strength tests of jack-pine poles in Minneapolis, from October 20 to November 12.

E. M. HONAN observed field trial installations of drop wire in the territories of the New York Telephone Company, the New Jersey Bell Telephone Company and The Southern New England Telephone Company.

GENERAL STAFF

E. P. CLIFFORD, Vice-President of the Laboratories, died Sunday, December 16. He entered the Western Electric Company in 1892 as an office boy, and became Cashier of the New York office some six years later. After experiences as Chief Clerk at Chicago, Philadelphia and New York, he became Assistant Manager of the New York House, and in 1911 its Manager, with supervision of the

Boston, Philadelphia and Pittsburgh Houses. In 1917 he was appointed Eastern District Manager of the Western Electric Company. On July 1, 1918, Mr. Clifford became Office Manager of the Engineering Department. A year later he became Commercial Manager and his responsibilities were gradually extended to embrace all non-technical activities. In 1925 the Engineering Department became Bell Telephone Laboratories, Incorporated, and Mr. Clifford, as Vice-President, was placed in charge of the General Staff Department.

G. B. THOMAS attended a dinner of electrical engineering students at Massachusetts Institute of Technology, at which the Bell System cooperative course was discussed. Mr. Thomas also addressed a group of senior students of electrical and mechanical engineering at Cornell University on December 14.

JOHN MILLS addressed the Central Association of Science and Mathematical Teachers at Chicago on December 1, on "Through Electrical Eyes." On December 13, Mr. Mills spoke before the Engineering students of Toronto University, and on the following day, before employees of The Bell Telephone Company of Canada in Toronto, on recent developments of these Laboratories.

S. P. GRACE included in his lecture program for December talks before the Rotary Club of Brooklyn, on December 6; Sigma Xi Chapter of McGill University, Montreal, on December 19, and employees of The Bell Telephone Company of Canada, Montreal, on December twentieth.

R. A. DELLER spoke on television before a group of Student Engineers at the New York Telephone Company Headquarters. "Through Electrical Eyes" was the subject of a talk given by him on December 4 before the A. S. M. E., A. I. E. E. and the Providence Engineering Society at Brown University.

EDWARD AIKEN, a porter in the Plant and Shops Department, died on November 17. He had been with the Laboratories since March, 1927.

L. S. O'ROARK spoke on the electrical transmission of personality before the Buffalo Section of the A. I. E. E. on December 14.

W. F. JOHNSON AND B. B. WEBB were in Trenton, Lawrenceville and Princeton, New Jersey, in connection with commercial matters involved in the installation of four short wave radio transmitters which the Laboratories are manufacturing for the Long Lines Department, American Telephone and Telegraph Company.

P. MAY has been assigned to duties at the Radio Station at Lawrenceville where he will handle the commercial phases incident to the installation of the short wave transmitting sets.

H. W. DIPPEL recently visited the Corning Glass Works, Corning, New York, to arrange for the purchase of glass needed for the enlarged tube shop program.

PATENT

W. B. WELLS visited Schenectady, and J. W. Schmied and P. C. Smith went to Washington, in connection with the prosecution of patents.

Club Notes

The next dance of the Club will take place on Wednesday, February 6, 1929. The music will be Herbert Hood's, and D. R. McCormack is arranging something very special by way of surprise. Tickets are $1.00, and are obtainable from D. D. Haggerty or the departmental representatives.

Urged by importunate Brooklynites, the dance will be held at the Hotel St. George. Contrary to the stubborn preconceptions of out-of-towners, Brooklyn Heights is quite as accessible for the average Club member as Manhattan. The I. R. T. thoughtfully built the Clark Street Station in a sub-cellar of the St. George — a fact to be remembered by Jerseyites, who will find that the trip from Cortlandt Street to Clark Street is a matter of only fifteen minutes.

Bowling

During the first half of the present season the amazing record of one hundred per cent attendance was established. One hundred and sixty men have bowled every Friday evening for fourteen weeks, and four additional alleys have been reserved for those who are not members of the regular league. These men, though not eligible for league prizes, will substitute in the order of their averages, for possible absentees of the league teams.

Club records show a decided improvement over last year's scores. There is keen competition for the various prizes to be awarded. Special interest is shown in the D. D. Haggerty Trophy, which goes to the bowler rolling the highest score for the entire season.

On November 23, the league officers expressed the season's greetings by donating two turkeys, to be awarded as prizes for the evening's highest scores. T. C. Rice and N. Scribner, each, to borrow a phrase from another sport, "got a birdie".

Hiking

The final event of the hiking season, on Sunday, November 25, narrowly escaped the blight of superstition. Of thirteen who entrained for Tuxedo only twelve were in evidence at Tuxedo station. But the satisfaction of those who had advocated drawing lots to decide which member of the party should be thrown overboard was short-lived. The thirteenth hiker, after buying a bar of chocolate to round out his luncheon, rejoin the group and the hikers gaily hit the trail for Mt. Ivy.

Snow had not yet fallen in the city, and the party was unprepared to find it underfoot (as much as one-quarter inch of it, in spots). No casualties resulted from this cause, however; the one snowball thrown, missed.

By way of the T-MI (Tuxedo-Mt. Ivy) trail and voluntary detours, the hikers wound their way through the Ramapo hills to Ladentown. Since the party was still full of vigor, though the scheduled hike had been practically completed, plans were revised, and the hikers swung down the road to Suffern. Such energy was bound to be rewarded, and it was,

when the party came upon a cider mill and stopped to sample its product. Much refreshed, the group stepped out with a will and reached Suffern not merely in time for the train, but with ample leisure for a sumptuous repast in a nearby lunch wagon. And so to home!

Though the official hiking season is over, the committee is always glad to get in touch with Club members who are interested in that form of recreation. If you have not already made yourself known to them, call Miss Barton, extension 857, or Alexander Grendon, extension 637, and make sure to be informed of the hiking Club's further activities.

Basketball

The Laboratories team is tied for first place in the Bell System League, in spite of a handicap incurred at the start, when it lost its first game to the Installation Department of Western Electric. A number of ardent rooters have been witnessing the games, and Manager Granville Matthews is confident that our team will repeat the splendid showing it made last year. On Monday and Friday evenings, games are played at Stuyvesant High School; on Wednesday evening, at Erasmus Hall High School. The games begin at 8:30, and are followed by dancing.

The squad: Gittenberger, C. W. Maurer, Steinmetz, Christ, Cahill, Kirsch, Keogh and West.

Indoor Golf Tournament

First prize in the December indoor golf tournament was won by J. G. Dusheck, who defeated R. J. Nossaman two up. As a result, Mr. Dusheck, who obviously needs it least, has a season membership in the Indoor Golf Course of America.

With memories of Christmas window-displays, the entrants rather expected to see a toy elephant in the bushes of the thirteenth hole, or to hear the rattle of an electric train among the green valleys of the course. So realistic was the scenery that players were seen trying to open the swinging door of a supposed locker room.

Seventy-two entrants played twice around and G. A. Brodley won the medal offered for low medal score. The sixty-four who qualified were divided into two groups of four flights each. Group 1, Flight A was won by R. J. Nossaman, who early established a lead over N. Thorne, and finished at the Fifteenth, four up. Other winners in this group were R. Koernig, I. W. Whiteside, and J. A. Hall. J. G. Dusheck took the final match of Group 2, Class A from T. C. Rice by six holes. Scoring six "holes in one," and his usual coolheaded putting contributed to this victory. E. H. Clark, J. M. Heywood, and E. K. Ebehardt were the other winners of this group. Each winner in the two groups received a prize and the respective winners of Class A played off for the special prizes donated by the management. In this contest, Dusheck took the lead on the third hole. Nossaman came up even, but lost his lead at the ninth. He was two down at the sixteenth, and by a twenty-inch putt lost the seventeenth hole and the match.

The next indoor tournament will be held on January 30 on the same course.

Club Elections

Those elected as Club officers for the coming year are: O. M. Glunt, president; H. F. Dodge, first vice-president; Marian Kane, second vice-president; A. C. Thoesen, Tube Shop

representative; J. W. Hultquist, Research; P. B. Fairlamb, Systems Development; and J. C. Kennelty, Commercial.

WOMEN'S INTERESTS

Swimming

Two swimming classes will again be conducted: one on Mondays from 7:00 to 7:30, starting January 7; the other on Wednesdays, from 5:30 to 6:00, commencing on January 9. The courses will consist of eight lessons covering a period of ten weeks at a charge of $2.50. They will be given at the Carroll Club, Madison Avenue and 30th Street, under the tutelage of Miss K. Spranger.

Basketball

The Bell System Basketball League, which this year has included the girls' teams, has provided a definite schedule of games. Two have been completed, with three more to be played on the evenings of January 7 at St. Luke's court, and January 16 and 30 at Erasmus Hall High School. Games commence at 7:30 and dancing follows.

The Laboratories team played two games outside its regular schedule, winning on each occasion. The first engagement was with the Federal Reserve team; the other, an exhibition game with the Long Island Division of the New York Telephone Company. Further outside games are to be booked. On our squad are Ann Barioni, Marie Boman, Marianne Grimm, Lilliam Kaempffe, Dorothy Murtha, Marie O'Neill and Natalie Skinner.

Bowling

Four women's teams have been bowling regularly every Friday since October 19, 1928 at Dwyer's. Though the women's bowling club is a new departure, it has become an unusually popular activity. Novices desiring an opportunity to play may arrange through Marion ane or Leona Feil to act as substitutes for members of the regular teams. Prizes will be awarded at the close of the season.

Christmas Poster Contest

After careful consideration, the committee in charge of the Christmas Poster Contest selected fifteen of the best posters, submitting these for final judging to two well-known commercial artists. The winning poster was reproduced and displayed on the bulletin boards during the Christmas season. It was made by E. Alisch, of the Equipment Drafting group who was awarded a prize of a ten-dollar gold piece.

Club Calendar for January

FRIDAY, 4: Bowling, 5:45

MONDAY, 7: Basketball, Men, Bell System League, Stuyvesant H. S., 8:30
- Basketball, Women, St. Lukes gymnasium, 5:30
- Bridge, Men, Room 275, 6:00
- Swimming Class, Women, Carroll Club, 7:00

TUESDAY, 8: Basketball, Men, Interdepartmental League, Labor Temple, 5:30

WEDNESDAY, 9: Basketball, Men and Women, Bell System League, Erasmus Hall H. S., 7:30
- Glee Club, Rest Room, 5:10
- Swimming Class, Women, 5:30

THURSDAY, 10: Basketball, Men, Interdepartmental League Labor Temple, 5:30
- Orchestra, Rest Room, 6:00

FRIDAY, 11: Bowling, 5:45
- Bridge, Women, Rest Room, 5:10
- Basketball, Men, Bell System League, Stuyvesant H. S., 8:30

MONDAY, 14: Basketball, Men, Bell System League, Stuyvesant H. S., 8:30
- Basketball, Women, St. Lukes gymnasium, 5:30
- Bridge, Men, 6:00
- Swimming Class, Women, 7:00

TUESDAY, 15: Basketball, Men, Interdepartmental League, Labor Temple, 5:30

WEDNESDAY, 16: Basketball, Men and Women, Bell System League, Erasmus Hall, 7:30
- Glee Club, 5:10
- Swimming Class, Women, 5:30

THURSDAY, 17: Basketball, Men, Interdepartmental League, Labor Temple, 5:30
- Orchestra Rehearsal, 6:00

FRIDAY, 18: Bowling, 5:45
- Bridge, Women, 5:10
- Basketball, Men, Bell System League, Stuyvesant H. S., 8:30

SATURDAY, 19: Commercial Chess League, W. E., vs. B. T. L.
- Basketball, Men, Bell System League, Stuyvesant H. S., 8:30

MONDAY, 21: Basketball, Women, St. Lukes gymnasium, 5:30
- Bridge Tournament, Men, W. E. Co., vs. Bell Tel. Lab.
- Swimming Class, Women, 5:30

TUESDAY, 22: Basketball, Men, Interdepartmental League, Labor Temple, 5:30

WEDNESDAY, 23: Basketball, Men and Women, Bell System League, Erasmus Hall H. S., 7:30
- Glee Club, 5:10
- Swimming Class, Women, 5:30

THURSDAY, 24: Basketball, Men, Interdepartmental League, Labor Temple, 5:30
- Orchestra Rehearsal, 6:00

FRIDAY, 25: Bowling, 5:45
- Bridge, Women, 5:10
- Basketball, Men, Bell System League, Stuyvesant H. S., 8:30

MONDAY, 28: Basketball, Women, St. Lukes gymnasium, 5:30
- Bridge, Men, 6:00
- Basketball, Men, Bell System League, Stuyvesant H. S., 8:30
- Swimming Class, Women, 7:00

TUESDAY, 29: Basketball, Men, Interdepartmental League, Labor Temple, 5:30

WEDNESDAY, 30: Basketball, Men and Women, Bell System League, Erasmus Hall H. S., 7:30
- Glee Club, 5:10
- Swimming Class, Women, 5:30
- Indoor Golf Tournament, Men

THURSDAY, 31: Basketball, Men, Interdepartmental League, Labor Temple, 5:30
- Orchestra Rehearsal, 6:00

BELL LABORATORIES RECORD

1800-PAIR CABLE
By W. C. Redding

ATOMIC PHYSICS AND CIRCUIT THEORY
By E. Peterson

PRIVATE BRANCH EXCHANGES
By R. W. Harper

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An Introduction to "Speech and Hearing"

By H. D. ARNOLD
Director of Research

With the publication of "Speech and Hearing" by Harvey Fletcher, Acoustical Research Director, the fifth book of the Bell Telephone Laboratories series comes into being. An introduction to this volume, contributed by Dr. Arnold, is here reprinted.

THE atmosphere of sounds in which we live ministers so constantly to our knowledge and enjoyment of our surroundings that through long familiarity we have come to feel, if not contempt, at least indifference toward the marvelous mechanism through which it works. Hearing, we are inclined to consider as little a matter for concern as breathing; and so long as our own faculty remains unimpaired we feel little curiosity concerning the provisions of nature either for ourselves or for others. When we hear too faintly or indistinctly we know we need only trace the sound to its source to hear its perfect form, for that is the method we have used from childhood in investigating the sounds of our immediate neighborhood.

Now with one broad sweep the barriers of time and space are gone and all the world becomes our vocal neighborhood. No longer can we transport ourselves to the origin of a sound and thus become convinced that we are hearing it aright, for that origin may be thousands of miles away or may have vanished years before; and so we must establish a new method to measure the accuracy of the copy which reaches our ears. We must also find a clearer index to our satisfaction in it, for we are no longer concerned with the immutable provisions of nature but may approach at corresponding expense whatever perfection we may demand in our instruments of translation and reproduction. Thus the telephone and the phonograph should excite a keener interest in how we hear and in what measures our satisfaction in the speech and music they provide.

Our ears are only machines to translate air waves into a form suited to stimulate the auditory nerve;

and as machines we may measure and describe them in the same terms that apply to devices we ourselves construct. We may compare them as to performance, and may accommodate our devices to their requirements. But, to understand the mechanism of the ear is by no means to understand the act of hearing, for we have not heard until the brain has perceived the message sent by the auditory nerve. We cannot explain in precise mechanical terms how this is done, nor indeed have we any very clear comprehension of the process at present. Some important factors relating to the process of hearing we can, however, determine by measuring the least changes in sound which can be detected under a variety of conditions of pitch, loudness, and accompanying noise. Thus we may obtain a quantitative means of comparing individuals in this respect, and establish a standard of average hearing.

There is a most important factor in hearing, however, which is much more difficult of analysis and measurement. This is the individual's ability to recognize small defects in those sounds with which he has become especially familiar. We all know how quickly we note a slight change in a friend's voice, and with what uncanny skill a trained musician will detect minute imperfections in very complex sounds. Our approach to a quantitative understanding of the importance of this must be by an indirect method. First we must construct devices so perfect that even the keenest ear cannot find a flaw in their rendition, and then step by step we may introduce measured imperfections until an observer can detect a fault. In the response of individuals to this test there will, of course, be great differences; but when we have collated opinions from a wide variety of observers we may forecast in a reasonable way the degree of mechanical perfection that may be demanded of our instruments.

This, then, has been the philosophy of the investigation of hearing which has been carried on in Bell Telephone Laboratories during the past fifteen years: to get an accurate physical description and a measure of the mechanical operation of human ears in such terms that we may relate them directly to our electrical and acoustical instruments; to test the keenness of the sound-discriminating sense and find what is the smallest distortion which the mind can perceive and how it reacts to somewhat larger distortions; and thus to reach a reasonable basis of design both for separate instruments and for systems, as a whole, to give a proper balance between cost and performance.

With hearing, speech and music are linked inseparably for they only bring a meaning through our aural sense. It is an instinctive first thought that they must be heard to be criticized. They can, nevertheless, be investigated by mechanical means and be described in the same physical terms that we use in describing hearing; and thus to an extent we may consider them both objectively. But if we attempt to divide the study between speech and music we come at once upon the difficulty that speech conveys information by intonation as well as by articulate syllables; and this makes it infeasible to set a definite boundary between them. A division, however, between vocal sounds and instrumental sounds proves more useful, for in the one case we are limited by our vocal organs which we must take as they are, while in the other

we have a definite control and can adapt the nature and complexity of the sounds produced to conform to our sense of hearing and our musical appreciation. The investigation of speech and music has been governed by these general considerations. An attempt has been made to establish in definite terms the performance and limitation of the voice and, although so far in considerably less detail, to find the corresponding factors in instrumental music.

With a clear knowledge of the nature of the sounds that we must produce and the accuracy with which we must maintain their form, there remains the problem of securing instruments which are sufficiently refined for the purpose. Instruments of remarkable precision are required in the conduct of the investigation, since if we are to measure the smallest detectable variations in sounds we must obviously use equipment which is capable of a degree of exactness beyond these small quantities. Such instruments would appear at first sight not to have much utility outside the laboratory, since they are costly and often complicated and difficult to adjust.

It is interesting to note, however, that some of the instruments, in essentially their original laboratory form, have found other important uses. Indeed, a surprising number of modern acoustical accomplishments have come about through the use of slightly modified forms of the apparatus which was originally developed for these investigations. Modern phonographic records are produced with an electrical transmitter which was developed in the very early stages of these studies; and radio broadcasting has grown up around this same "microphone." The reproducing equipment of the modern phonograph and of the radio were predicated directly upon these investigations; and talking motion-pictures owe their success and much of their apparatus to this same source.

Although the results which relate to normal speech and hearing are naturally the most familiar and widely known, there have also been important outgrowths in the way of aids to those handicapped in one or the other of these faculties. In establishing the functioning of the average ear it was obviously necessary to investigate a large number of cases and among them some which departed rather widely from the average. For this study an instrument was devised, now known as the audiometer, which has put within the reach of all who need it the possibility of an accurate measure of their hearing. In quite analogous fashion there grew out of the investigation of the limits of hearing a better knowledge of ways to provide aids for those partially deaf; and it has even become possible to provide means of speech for some persons whose vocal cords are gone.

Valuable as these results are, economically the most important outcome of the work has been the increase of exact knowledge as to the requirements and limitations to be placed upon the transmission of speech in the telephone system. As time goes on there must be an evolution toward even greater perfection in those particular elements which are most important to intelligibility. The system is so large that the cost of such an evolution is immense and changes undertaken without an accurate knowledge of their value might lead to burdensome expenditures for disproportionate results; but, with the

facts established by this investigation in hand, we can weigh any contemplated change and judge whether it is the one that offers most improvement at the moment and what its ultimate effect will be in its operation with other elements of the system.

The work that Doctor Fletcher discusses drew at the start on all the acoustic knowledge available in the literature and during its progress every effort has been made to use to the best advantage the information found by other experimenters. For the most part, however, he describes experiments performed and conclusions reached in Bell Telephone Laboratories during investigations, captained in their early stage by Doctor Crandall and himself, for which since Doctor Crandall's death he has had the full responsibility. No one can speak with better knowledge of the facts or with more complete authority for the opinions he expresses.

The work is not complete—indeed some parts of it are hardly more than started; yet its results have been so great, both for the original purpose which was planned and for the many issues which have since arisen, that it presents a unique exemplification of the worth of systematic and sustained research; and Doctor Fletcher is to be congratulated that he has seen it through with such clear vision as permits its presentation in its present form.

Development of the 1800-Pair Cable

By W. C. REDDING
Apparatus Development Department

OF the developments that during the past half century have brought the telephone system to its present state of usefulness and efficiency, none, perhaps, is more typical of steady improvement than is lead-covered cable. The growth from the fifty-pair of 1888 to the 1200-pair cable of 1912 has already been described in the RECORD.* As is commonly the case, however, difficulties become greater the further a development is carried. The step from 1200 to 1800 pairs, taken by the new development, although it represents no greater percentage increase in size than many of the preceding steps, and is even smaller than some, is a noteworthy achievement because with each increase in the number of pairs, and each decrease in size of wire, the difficulties of manufacture become greater.

With the increasing congestion in metropolitan areas, available space beneath the streets—where cables must be placed—is rapidly being used up. Added demands for power, light, water, transportation, and other utilities all require their share of this space. Obtaining a fifty per cent increase in the number of telephone wires that may be run through a duct is thus a real contribution to the growth and development of densely populated districts, and promises further economies in this and also other situations.

The largest cable existing previously used twenty-four gauge conductors wrapped with paper one-quarter inch wide and two and one-half mils thick, and its 1212 pairs, so insulated, were contained within a lead sheath of about two and five-eighths inches outside diameter. Cables of this diameter are the largest that can be pulled into many existing ducts, and so this outside diameter is one of the limiting factors of exchange-cable design. The problem, therefore, is not merely to make a cable with a greater number of conductors but to change the design and methods of manufacture so that the larger number of wires can be contained within the same size of sheath.



Fig. 1—A short length of 1200-pair cable showing layered construction

Obviously there are two possibilities; either the size of the conductors

* BELL LABORATORIES RECORD, *Vol. III, No. 5, pp. 146-152, January, 1927.*

or the thickness of the paper insulation may be reduced. There are difficulties involved in such reductions, however, both in the manufacture of the cable and in handling it after its completion. A cable must be pulled into a duct from one manhole to the next, and possibly in the course of its life may be pulled out of one duct and into another. This pulling subjects the cable to strains and there is a possibility of breaks resulting in the conductors if they are too weak. Besides this the lengths of cable must be spliced in each manhole and because of the difficulty of handling smaller wires they cannot be reduced too far in size. In addition the factor of resistance can never be overlooked. The smaller the conductor the higher is the resistance and the greater, therefore, are the transmission losses.



Fig. 2—In this cross-section of the 1200-*pair cable also the layered construction is clearly evident*

In the course of development, projected to overcome these difficulties, many experiments were tried. Wires of different materials were experimented with to find out whether tougher substances, such as hard copper or bronze, would not add enough strength to offset a decrease in size. Results were not very satisfactory. The harder wire was springy and difficult to handle at the splices. Cables of soft copper but of smaller sizes were also experimented with and it was found that wire as small as twenty-seven gauge could be used.

Then, attention had to be given to the matter of paper. The thickness used with the 1200-pair cable was chosen principally for reasons of strength. In building up the cable the wires must be crowded together with considerable pressure and in handling the cable after completion, particularly in bending it, similar pressures are developed. If the paper is too thin there is danger that the conductor may cut through it at such times.

With smaller conductors it is possible to use thinner paper but in attempting to use paper thinner than used in the 1200-pair cable another difficulty arises. In wrapping the paper strip around the conductor in the manufacturing process, certain tension must be maintained and with too fragile a paper tearing is apt to



Fig. 3—A cross-section of the 1800-*pair cable shows how the eighteen units are formed into the final cable*

result. This difficulty was partly overcome by the Western Electric Company through improving its insulating machinery so that thinner paper could be satisfactorily used. It was thus possible to employ paper which was appreciably thinner than the two-and-one-half-mil paper of the earlier cable.

While all this work was going on another development had been made which changed the arrangement of the pairs of conductors inside the sheath. The basic unit of all telephone cables of this type is the pair: two conductors, each insulated with paper, twisted together. In practically all the earlier cables these pairs were laid up in concentric layers. Each layer was spiraled around the layer beneath it, and the direction of the spiral of successive layers was reversed. This gave a firm body that could be easily handled.

The new development built up small unit cables, each of 101 pairs for the 1818-pair cable, and then assembled these in a long spiral to form the complete cable. This new method brought about certain small savings due to a reduction in the take-up—or shortening of the effective length of the conductors due to stranding—and considerably simplified the manufacturing of the larger sizes of cable. It resulted in a more flexible core which is also important with the larger cables.

As a result of these various developments and improvements, an experimental cable was constructed with 1818 pairs of twenty-seven-gauge wire. Experiments in pulling this cable in and out of ducts indicated that a somewhat firmer core would be desirable. A cable of the same number of pairs but with twenty-six-gauge wire was then tried and found satisfactory. It is this cable that has now been standardized and will be used in the future in many of the large metropolitan areas and other places where conditions make it desirable.

In building up the new cable, two of the hundred-pair units are used as a center and around them are spiraled six other hundred-pair units. Around these are laid the remaining ten units to complete the full 1800 pairs. This may be seen in Figure 4, where the two inner groups point vertically up-

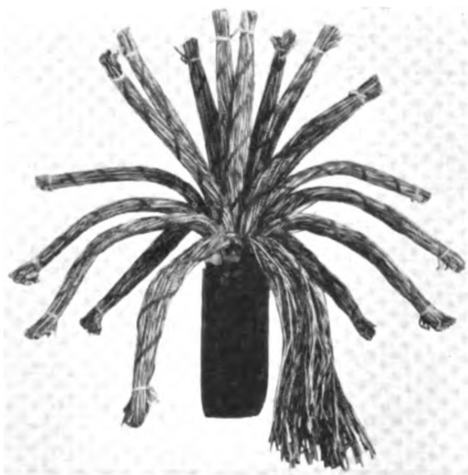


Fig. 4—The arrangement of the eighteen units is here clearly evident

ward, the next layer of six units points out at an angle of about forty-five degrees, and the outer layer of ten units is bent down.

For convenience in identifying pairs for splicing, it is customary in all the larger cables to use several colors of paper to insulate different groups of pairs. In the 1200-pair cable, for example, the pairs in each group all have insulation of the same colors, which are different for adjacent groups. In

all, six colors are used. Each group is distributed over the whole or part

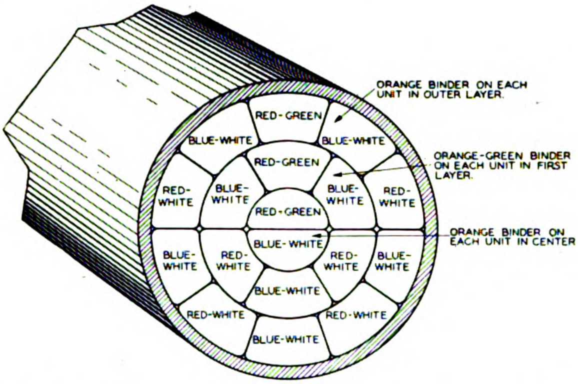


Fig. 5—The symmetry of the color arrangement of the hundred-pair units with reference to the three red-green groups makes identification of groups comparatively simple

of one or more of the annular layers, and the same color appears only in widely separated parts of the cable. In making a splice each group is bunched together and joined to the corresponding group of the continuing cable.

This method is facilitated by the new construction, as the hundred pairs of a unit are all of the same color and already bunched. Each unit in addition is loosely bound with cotton threads, those of adjacent layers being of different colors, which makes it easier to identify corresponding units. A simplification of the color scheme has been developed which is indicated in Figure 5. The two wires of a pair are always insulated with differently colored paper and one of the two inner units uses red-green and the other blue-white paper. The next layer has one unit of red-green, and on each side of it a blue-white unit, followed by a red-white unit, and so on. The outer layer is similarly built up with one red-green unit and then alternately blue-white and red-white units. As a result the cable is symmetrical in appearance when looked at from each end so that locating corresponding units in making a splice in a manhole is a relatively simple matter.

At the termination of these cables in central offices it is customary, for convenience in distributing the pairs to the main frame, to splice them into several small cables with double silk and single cotton insulation. In

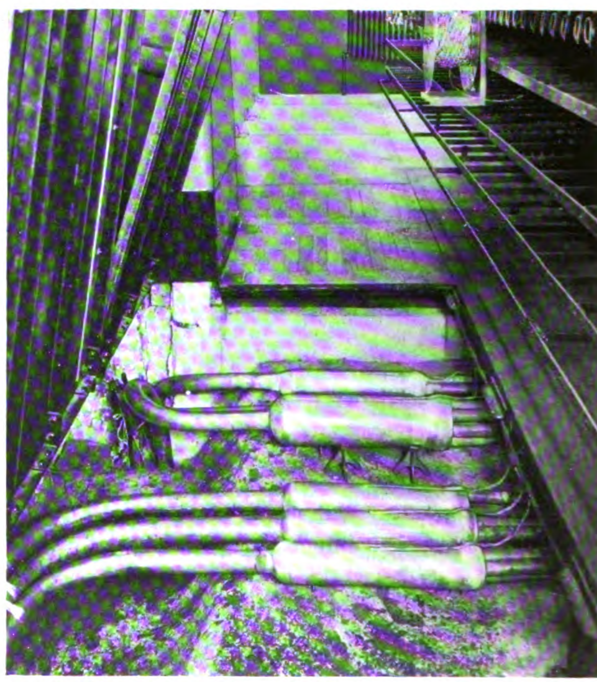


Fig. 6—The fourth cable from the bottom shows an 1800-pair cable spliced to nine 200-pair cables for distribution to the main frame

Figure 6 is shown such a splice where nine 200-pair are connected to one of the new 1800-cables. The 200-pair cables run under the floor for a few feet and then up the vertical side of the frame where they are fanned out and connected to terminal protector blocks. The amount of space required for fanning out one of the new cables can be seen in Figure 7. Each 200-pair cable requires about five feet of terminal strip so that nine rows of blocks, each about five feet high, are required in all. As a contrast a small piece of the 1800-pair cable is placed beside the terminal blocks.

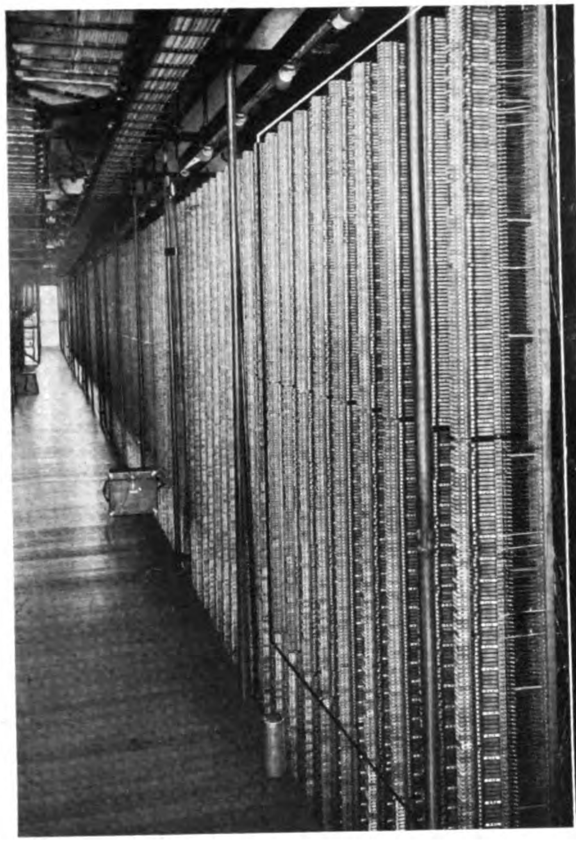


Fig. 7—Nine rows of terminal blocks—each about five feet high—are required to fan out an 1800-pair cable

These last two views were taken in the Cumberland Office of the New York Telephone Company in Brooklyn and show the termination of the first commercial installation of 1800-pair cable, which was completed in the spring of 1927. Since that time a limited amount of this cable has been manufactured on temporarily modified machinery. The Western Electric Company, however, has designed and is about to put into operation new and improved machinery in order that it may be in a position to take care of the demand that is expected for the new product.

Private Branch Exchanges

By R. W. HARPER
Systems Development Department

A CENTRAL office, functionally considered, is that part of a telephone system which connects any subscriber in the area served by it to any other in the same area, or which acts as the first of a chain of connecting centers when the subscriber called is at a more remote location. A private branch exchange serves a group of stations within a single establishment in a closely parallel manner. That there are 130,000 private branch exchanges in use in the Bell System is a striking fact which makes one realize the importance of this rapidly growing part of the telephone plant. In some of the larger cities P. B. X. attendants outnumber central-office operators; in Manhattan, for example, there are about 9500 central-office operators while the P. B. X. attendants number approximately twenty thousand.



Fig. 1—The 505 P. B. X. uses neither cords nor plugs; all switching is done by manipulating keys mounted on the face of the cabinet

In the very early days a single telephone in any one residence or place of business was ample. The telephone was so superior to former methods of communication, by mail or messenger, that its easy accessibility to each individual that might have occasion to use it never occurred to any one as being at all necessary. Nor did it seem necessary to have telephonic means of communication between persons within a single establishment—much smaller at that time than are some of our gigantic corporations now. As the telephone came to be used more and more, however, and as greater numbers of employees in every office or factory found occasion to take advantage of its time-saving possibilities, a demand naturally arose for more than one station in the larger establishments. There arose also a need for the telephone for intercommunication; a bookkeeper in the office found much time and energy could be saved if he could talk directly with a clerk in the shipping room. Out of these demands arose the private branch exchange, or P. B. X. as it is colloquially termed, a private central office serving directly its own stations.

A P. B. X. was not, of course, the



Fig. 2—A large 604-type P. B. X. installed in Bell Telephone Laboratories

only solution possible. There could have been the same multiplicity of stations within the establishment and the same possibility of intercommunication, had each station had its own line to the main central office and its own number. Any station could have called another by passing through the central office operator, and so far as the members of the organization were concerned there would have been little difference except that the station designation numbers might have been longer.

From the standpoint of some one calling in from the outside, however, there is a considerable difference. The outsider often does not know the name of the person he wants to talk to; he knows what he wants to find out or what knowledge he wants to impart but that is all. If for any establishment there were only a long list of names and numbers in the directory he would be helpless. Obviously the only satisfactory solution is to have but a single number for any one establishment and a single person—or, for the larger concerns, a single group of persons—to answer all incoming calls. This person, the P. B. X. attendant, with intimate knowledge of the organization could connect the incoming call to the station that could most effectively deal with it. Thus the need for an attendant was paramount in calling the P. B. X. into existance and the attendant is still of primary importance to the modern P. B. X. system.

If there are fifty telephone stations in the local establishment they will never all want to talk with the outside simultaneously. At any one time some stations will not be in use at all and some may be talking to other local stations, leaving only a small remainder making demands for outside service. The ratio of central-office trunks to stations, therefore, is always less than unity although it varies over a considerable range depending

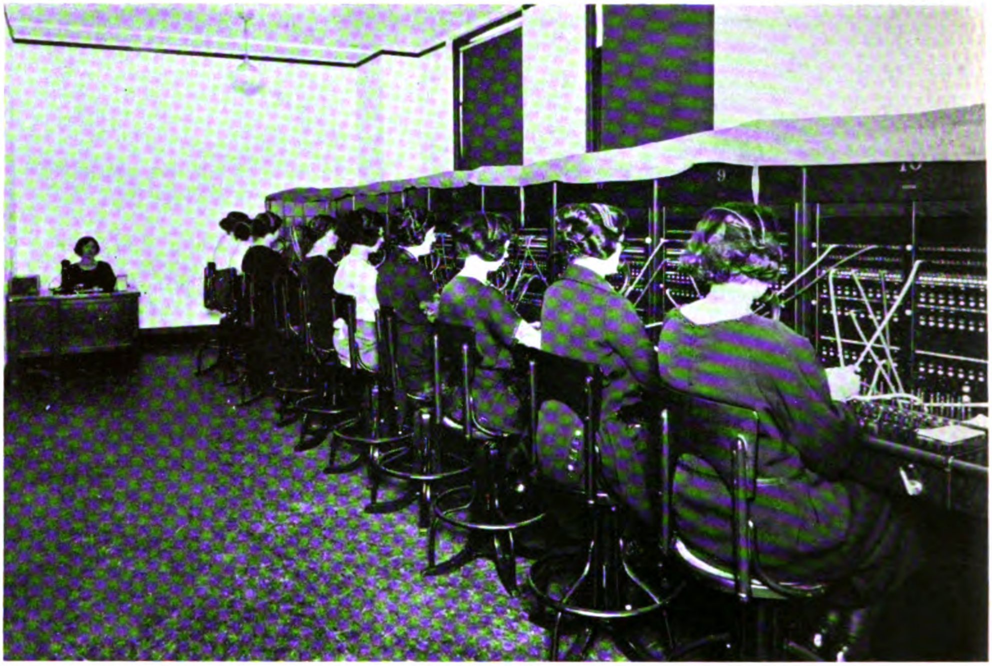


Fig. 3—A medium sized P. B. X. of the manual type is the 600-C

on the type of business. The attendant and the P. B. X., of course, always partially, and occasionally entirely, offset the savings due to the reduction in number of trunks. The attendant, however, performs so many useful services that she is generally regarded as an asset rather than an expense.

Differences in types of business as well as differences in size naturally affect the P. B. X. equipment furnished for the subscriber. In some organizations most of the calling is between members within the organization, whereas in others practically no local calls are made. In some places conditions favor dial service while in others the manual system offers certain advantages. Differences in the number of stations to be served necessarily make a difference in the type of P. B. X. furnished. Thirty-five varieties of P. B. X. have been made in the past and probably more will be built in the future as methods of doing business change and as telephone apparatus and equipment improve. There has never been this number in standard use, however, at any one time. At present only six types are standard and stocked and this number probably fairly represents the number standardized at any one time in the past.

In the manual class the range of size varies from the small 505 type, with a maximum of seven stations and three central-office trunks, to the large 604-C which, as used by the Consolidated Gas Company of New York, has 1650 station lines, 221 trunks to central offices, and 175 tie lines to other branch exchanges, and requires 42 attendants during the busy part of the day.

The small 505-type board uses no cords or plugs but all connections are made by keys on the front of the board. It is so small that it can be

placed on an ordinary desk, and may be operated by a clerk who may also have other duties. Contrasting with this the larger exchanges, such as the one in our own Laboratories, have all the appearance of a central office. Between these extremes are other types and sizes such as the 550* and the 600-C.

Each type of board is made necessary by the conditions of service that it has to meet and by the number of lines that it must serve. The cordless 505 type is compact and seems very simple but actually would become difficult to operate if the number of lines were increased to any great extent. To locate an operated key from the large number all exactly alike becomes somewhat trying. A cord plugged into a jack, on the other hand, is easy to see and so as the number of lines increases better results are secured with cords.

The No. 1 and No. 2 intercommunicating sets, which do not require attendants for local calls, are interesting because of their small size. Lines run from each station to every other, and each station is in reality its own P. B. X. as a key is depressed corresponding to the line wanted and no other switching equipment is required. Except for this very small unit, private branch exchanges not requiring an attendant for local calls have been designated for the larger installations only. The present standards are the 700 and the 740** dial-types, the former of which may have any capacity up to one approaching that of a central office. Both of these boards may dial an outside number without the aid of the local attendant. The 740-A, only recently developed, has a maximum capacity of eighty-eight station lines and will serve subscribers with a smaller number of local stations.

There is a large and increasing demand for tie-line intercommunication

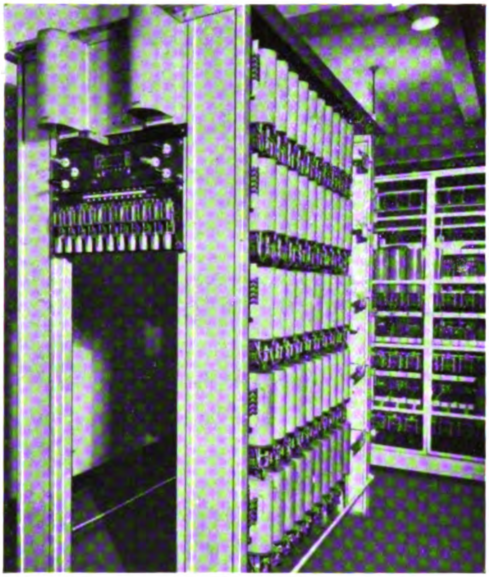


Fig. 4—Dial-type private branch exchanges have usually been made in the larger sizes as indicated by this section of a 700 type

between P. B. X.'s. Large organizations, such as public service companies, often have a number of private branch exchanges located at different points throughout the city. The tie-lines may be arranged for dial or manual service, depending upon the type of P. B. X. and the requirements of the subscribers. When tie-lines are provided between dial P. B. X.'s the circuits can be arranged, if desired, so that a station in one P. B. X. can dial any station in another. At Bell Laboratories there are direct tie-lines to and from nine other Bell System P. B. X.'s in and around New York City.

* *The latest design of this type, known as the 551, is described in* BELL LABORATORIES RECORD *for July, 1928.*

** *Described in* BELL LABORATORIES RECORD *for August, 1928.*

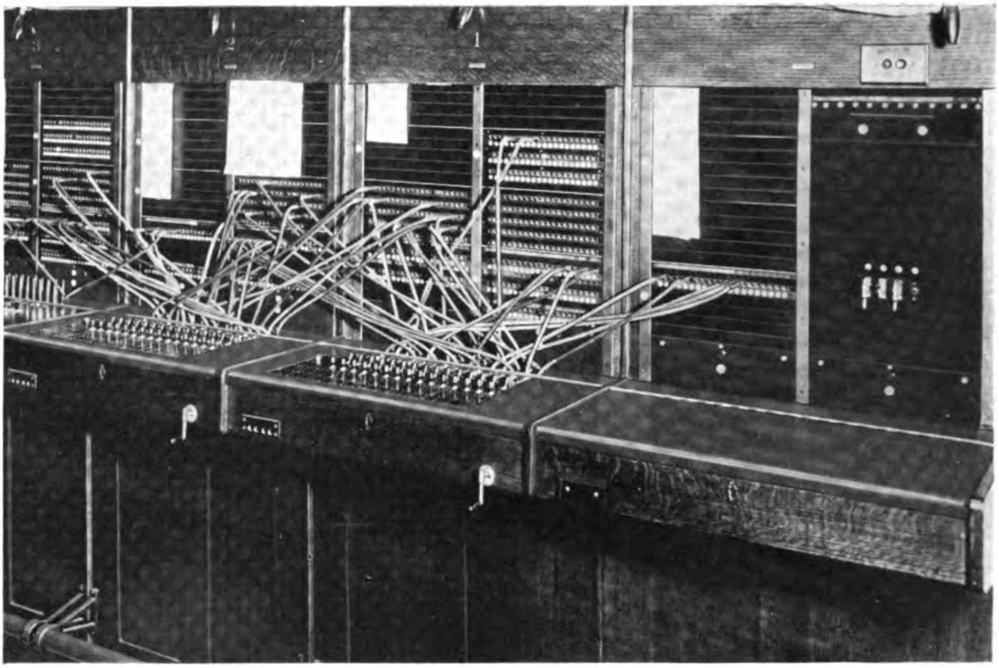


Fig. 5—A P. B. X. of the dial type as a rule has a group of manual positions for the answering of incoming calls. The above is a part of a 700 P. B. X.

Of the 115,000 P. B. X.'s manufactured by the Western Electric Company during the period from 1910 to 1926, 96% were of the small sizes. Of these 9% were of the No. 2 and No. 4 types, the latter of which is now no longer standard, the other 87% being about equally divided between the 505 and the 550 types. Naturally, there are fewer of the very large boards so it is not surprising that in this same period only a score or more of these have been manufactured, although additional sections are being made continually to take care of the expansion of the existing boards. These figures make it easier to understand that in some central offices in the business section of New York City approximately seventy-five per cent of the total working lines terminate in private branch exchanges.

Atomic Physics and Circuit Theory

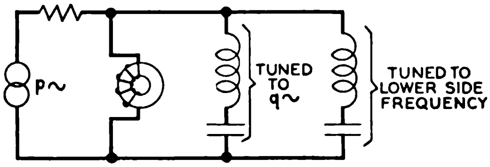
By EUGENE PETERSON
Research Department

IT has recently been suggested by R. V. L. Hartley that there appears to be a similarity between some of the phenomena observed in atomic physics and those found in certain non-linear electrical circuits. This idea is interesting and very important since it suggests the possibility of accounting on purely classical grounds for the methods used in calculating quantum phenomena. The non-linear circuits of interest here are of the variable reactance type such as the magnetic modulator for variable inductance, and the condenser transmitter for variable capacitance.

A number of years ago some of us in the Research Laboratory were working on magnetic modulator circuits to check theoretical speculations which were of considerable interest at that time. All modulators have this feature in common, that they distort the wave shape impressed upon them: a process which yields new frequencies related to those originally impressed on the circuit. If for example a pure sine-wave generator is connected to the modulator, then the new frequencies produced are harmonics, integral multiples, of the generator frequency. When two of these generators of different frequency are connected to the modulator (they may be the carrier and voice waves of the ordinary radio broadcast transmitter) we get, in addition to the harmonics of each of the generator frequencies, combinations between them, among which are the sum and the difference of the two original frequencies. The latter are known as side frequencies; they are evidently produced by the wave-distorting or non-linear properties of the modulator, since these new frequencies do not arise when ordinary non-distorting elements make up the circuit. In the magnetic modulator the non-linearity is provided by the magnetization characteristic when sufficiently large magnetizing forces are used.

The problems arising in modulator circuits are those concerning the relationship of these new current components to the original ones. Two of the properties of the modulator which are of interest in this connection are the stability, and the ratio of the side-frequency power developed to the signal power supplied; usually the latter is termed the modulating gain. In the first magnetic modulator circuit set up, we had three filters connected to the modulating coil: one to supply the carrier, the next to supply the signal, and the last to take off one of the side-frequencies to a load circuit. Even at the most favorable value of carrier voltage, the modulating gain was found to be too low with our hastily improvised arrangement and we set about the construction of a more efficient circuit. To do this the modulator coil was built up with very thin laminations of permalloy, and

the number of turns and the size of the coil were adjusted to draw maximum power from the two connected generators. When these changes were gradually incorporated in the circuit, the modulating gain rose until finally a curious phenomenon was noticed by E. T. Burton: the circuit became unstable, and a number of new frequencies were produced which apparently bore no relation to the



Circuit for the production of low-frequency oscillations. Current from the carrier frequency (p) generator, applied to the toroidal coil yields simultaneously a low frequency (q) current and the side-frequencies. A tuned circuit is provided for only one side-frequency — the lower

originally impressed frequency. These were made evident by a mushy note which was heard when a telephone receiver was connected in circuit. This effect obviously set a limit to the gain which could be usefully obtained and it seemed desirable to establish the reasons for its appearance.

The effects are more easily followed when we use simple tuned circuits instead of filters. In that case single frequencies are generated rather than the large number of frequencies which appeared in the filter circuit and gave rise to the mushy note observed. An approximate mathematical analysis of this simplified circuit was made. Assuming a magnetic core free from hysteresis and working under simple circuit conditions, it was found that the flow of the two side-frequencies changed the coil resistance to the two input frequencies. In the path of the higher impressed frequency p this resistance was positive; in the path of the lower impressed frequency q the resistance introduced by the flow of the upper side-frequency was positive but the resistance introduced by the flow of the lower side-frequency was negative. These conclusions were in complete agreement with those which had been found theoretically by Mr. Hartley in 1917, and which he had also obtained somewhat later in the case of a condenser transmitter. These conclusions are carried over unchanged to the higher order side-frequencies such as $2p \pm q$ and $3p \pm q$.

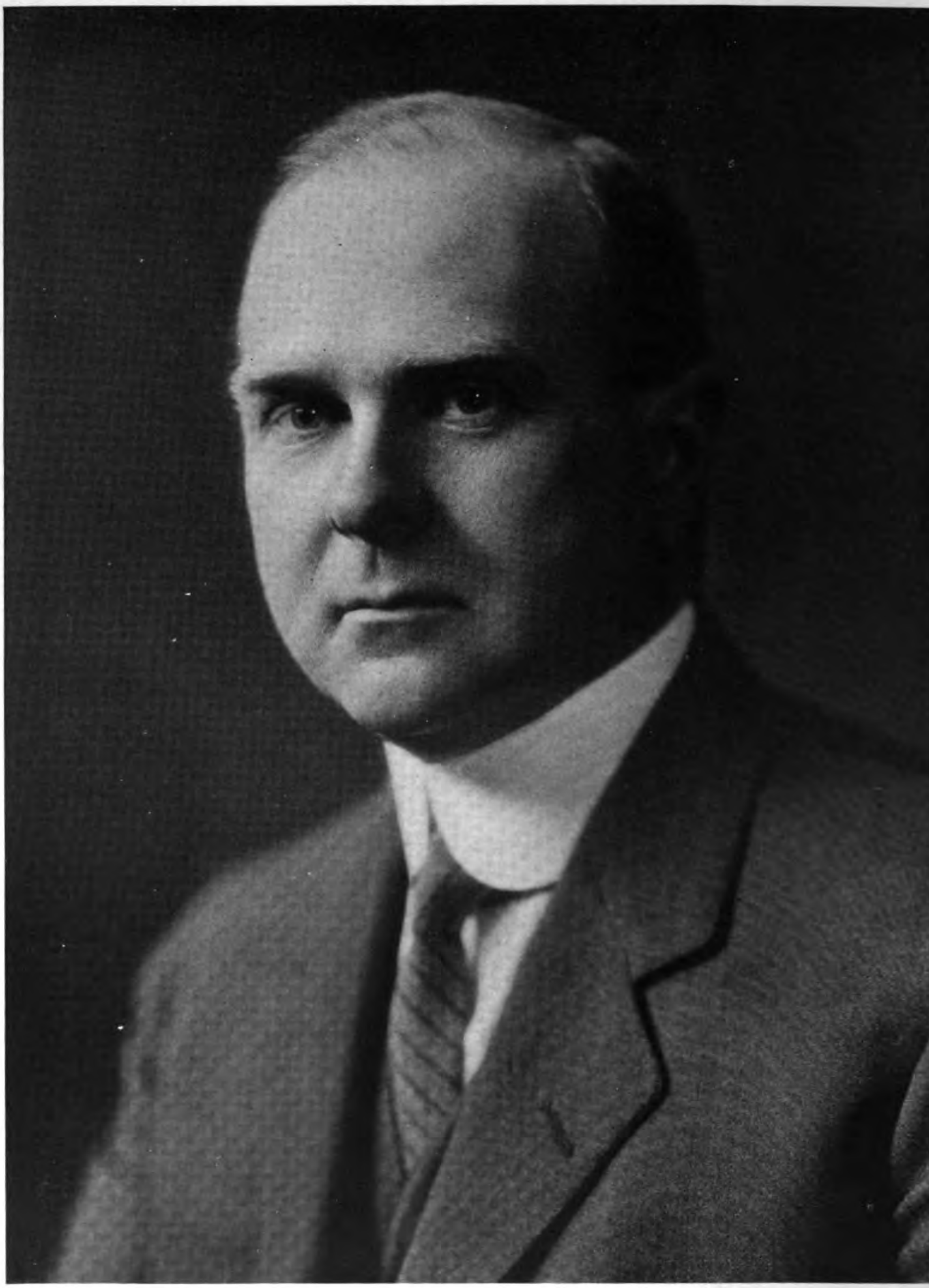
This idea of negative resistance enabled us to account for the experimental observation in a qualitative way at least, and justified the initial assumption that the non-linear magnetic characteristic, and not the hysteresis loop, was responsible for the effects. For if the upper side-frequency meets a high circuit impedance, so that the resulting current is small, and if the lower side-frequency meets a low circuit impedance, so that the resulting current is large, then the net effect of these two currents on the resistance to q will be negative. When this net effect, which depends upon the carrier amplitude, is great enough to make the total circuit resistance negative, and when the circuit reactances are nearly annulled, then oscillations will result and if the generator of frequency q be withdrawn, this frequency, together with its side-frequencies, will be sustained. It was with the simpler circuit shown that the theoretical conclusions were more definitely tested and found to be in general agreement. In order that sustained frequencies might arise the carrier was required to exceed a defi-

nite amplitude, the associated circuits were required to be fairly well tuned to the two frequencies involved and the resistances of the tuned circuits were required to be sufficiently small. In a circuit using filters these conditions are obeyed at a number of frequencies so that several currents are sustained.

To sum up these effects we may employ terms ordinarily used of regenerative vacuum-tube circuits, in which oscillation is produced by feeding current from the plate to the grid circuit in proper phase. The source of energy here is the plate battery, whereas in the magnetic modulator it is the carrier generator. For each, there is a critical value below which sustained oscillations cannot exist. Further, in the magnetic modulator case there is not merely one sustained oscillation, but at least two, which we have designated q and p-q. Neither can be sustained without the other, and if we introduce sufficient resistance to either q or p-q, or if we introduce sufficient reactance to either circuit both oscillations cease.

Mr. Hartley has suggested in a paper presented before the American Physical Society on December 29, 1928 that there is a striking resemblance between the phenomenon just described and the Raman effect in atomic physics. Raman found that in passing light of a definite spectral composition through certain liquids, the spectral composition of the emerging light was changed. New lines appeared, sometimes as pairs equally spaced above and below a line in the spectrum of the incident light, with the higher frequency line always weaker than the lower. In some cases only the lower frequency line was strong enough to be observed. Further, the interval between the new lines and the original lines from which they were displaced has been associated with a line in the absorption spectrum of the liquid; that is, the interval has been associated with a molecular resonance. To press the analogy with the modulator circuit, the frequency of the incident light corresponds to the supply frequency p, the molecular resonance frequency is q, the stronger observed line is the lower side-frequency p-q, and the weaker is the upper side-frequency $p+q$. The parallel is even more striking in the case of the condenser transmitter, in which the same type of effect occurs, and in which, moreover, the power involved is proportional to the frequency. This is suggestive of the quantum relation.

The importance of Mr. Hartley's suggestion lies not only in its application to the Raman effect but also in its application to the general field of atomic physics. The present effort in atomic physics is devoted to discovering methods such as matrix mechanics by which the observed effects may be computed, and the results are in many cases in excellent agreement with the facts. However, there does exist some question as to the physical significance of the quantities employed in these non-classical methods of computation. Following Mr. Hartley's suggestion it may be possible to compute these effects by treating non-linear mechanisms by ordinary mathematical means. If this should prove feasible a physical interpretation would be provided for quantum mechanics, and we should then have a classical mechanism capable of reproducing quantum phenomena.



HARRY PRESCOTT CHARLESWORTH

Entered American Telephone and Telegraph Company, Engineering Department, 1905; *Equipment and Transmission Engineer,* 1919; *Plant Engineer,* 1920; *Vice-President Bell Telephone Laboratories,* 1928

Harry Prescott Charlesworth

ON December twenty-seventh, Harry Prescott Charlesworth was elected Vice-President of the Laboratories. He will be in charge of its operations during Mr. Craft's absence.

After graduation by the Massachusetts Institute of Technology in 1905, Mr. Charlesworth entered the Engineering Department of the American Telephone and Telegraph Company, which was then located in Boston, and in connection with which one of the development and research laboratories of the Bell System was operated.

His first assignment was to the development of local and toll circuits and associated apparatus. In this work he was engaged for two years, until in 1907 the American Company moved to New York City.

During the next ten years Mr. Charlesworth was active in the development of toll operating methods and the general related engineering problems involved in extending and improving telephone service.

With the opening of the war he was specially assigned, as a result of his broad knowledge of telephone plant and its operations, to handle problems wherein the Bell System could be of assistance to the Government in the national emergency. In this capacity he was throughout the war active on communication facilities for army camps, naval bases, supply depots and particularly for the Government Departments at Washington, where he also rendered continuous assistance to the Telephone Company on general equipment and traffic engineering matters.

At the close of the war he took up dial-system development work and with the creation of the Department of Operation and Engineering, was appointed Equipment and Transmission Engineer under Vice-President Gherardi. A year later he became Plant Engineer of that Department, in which position he has been concerned with all phases of the engineering of the telephone plant and with relations with other wire-using companies.

Thus, throughout his telephone career of almost a quarter of a century, Mr. Charlesworth has taken an active interest in the development of telephone apparatus and equipment to meet telephone needs, and in the origination of proper operating methods for handling telephone traffic. His background of scientific training and long contact with the development and operating problems, and his proven ability to coordinate and advance the work of others, have resulted in constantly increasing responsibilities in the Bell System. And now with an experience well rounded by his supervision of plant engineering in general, he returns to his original interest in development by assuming leadership of the Bell Telephone Laboratories.

Development of Step-by-Step Line Finders

By W. L. DODGE
Systems Development Department

IN the early step-by-step exchanges a selector was provided for each subscriber's line. It made the first of a series of successive selections resulting in a connection to the line called. Selectors, however, are comparatively expensive mechanisms, and as they are in use only when the line is making an outward call a much smaller number of them would meet the requirements could some method be devised of connecting them to a line only while an outward call was being made. To the search for the most efficient method of doing this, much thought has been given and many studies made which, embodying themselves in laboratory development, have resulted in the step-by-step line finder. Although the mechanism itself is of the step-by-step type, the function it performs owes its inception to the panel system, a later development of the dial-system method of telephone switching.

The first step toward the more economical use of selectors was the introduction of the Keith or plunger-type line switch in 1907. This is a comparatively inexpensive switch one of which is connected to each subscriber's line. It starts operating as the subscriber lifts the receiver from the hook and completes a connection to one of a group of ten trunks leading to selectors before dialing is begun. Line switches of a large number of lines (the exact number being dependent on traffic conditions) have access to the same group of ten trunks with the result that the number of selectors is much smaller than the total number of lines.

The possible reduction in selectors depends for the most part on the number that may be reached by any one line, or conversely, on the number of lines that may be reached by any one selector. The smallest number of selectors that will give satisfactory service is fixed by the number of calls being placed at one time but only if each selector had access to all the lines could this lower limit be reached. With a lesser degree of accessibility the chance distribution of calls enters to require a greater number.

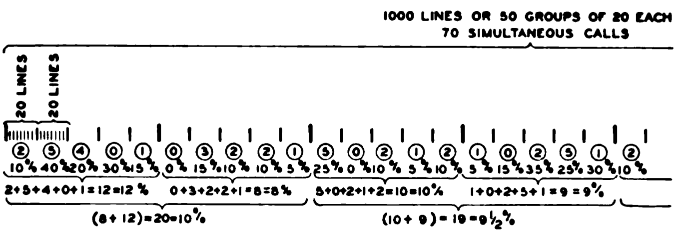


Fig. 1—*Diagrammatic representation of the advantages from greater mutuality between selectors and lines*

Consider for example a small central-office of one thousand lines over which a maximum of seventy outgo-

ing calls are made at any one time. As an initial assumption let each selector have access to twenty lines so that the thousand lines in the office may be divided into fifty groups of twenty lines, each group being served by a certain number of selectors. The seventy outgoing calls being made simultaneously will not, of course, be equally divided among these groups. Chance affects the distribution so that some groups will have more and others less than the average number. A possible distribution is indicated on Figure 1 in numbers written under each group. With this distribution and assuming that the number of selectors is to be so chosen that all outgoing calls can be handled immediately, there must be—in the case given—five selectors serving each group as that is the maximum number of calls occurring at the same time in any one group. The minimum number of selectors possible—seventy for the thousand lines if there were complete accessibility—is seven per cent of the number of lines while with the arrangement indicated, where each selector has access to only twenty lines, the selectors are twenty-five per cent of the number of lines.

In grouping lines an effort is always made to obtain a balance by so sorting the lines with lower or higher calling rates among the groups, that the average and peak calling rate for all groups is the same. Over a period of time, therefore, all groups will have had at one time or another the same number of simultaneous calls. The diversity indicated on Figure 1 is only that existing at any one moment. A few minutes later the grouping probably would be entirely different, with a group now having no calls perhaps then having five, and this shifting of calls would extend on through the larger groupings.

Increasing the accessibility by making each set include one hundred lines, indicated by the brackets on the dia-

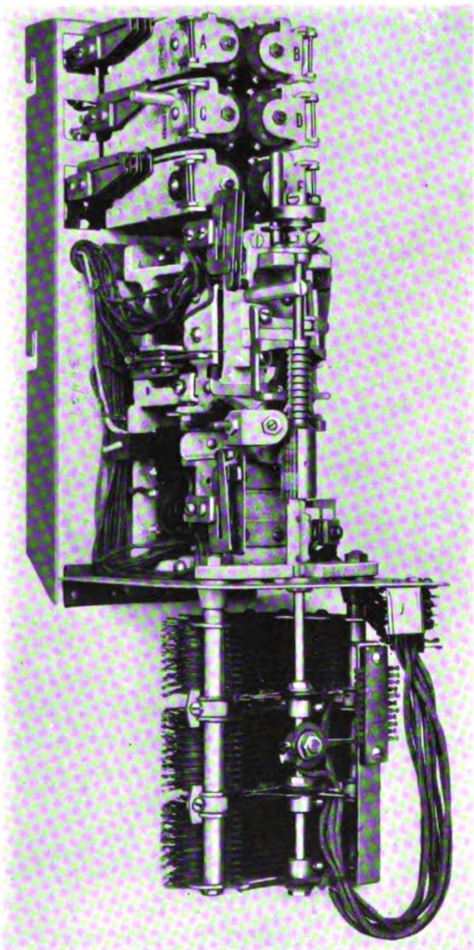


Fig 2—A step-by-step line finder showing its three banks. The commutator at the right between the middle and upper banks forms part of the vertical hunting circuit

gram, reduces the ratio of selectors to lines to twelve per cent. If the increase of accessibility is carried to two hundred lines the ratio of selectors to lines may be lowered to ten per cent. The actual possible decrease in selec-

tors with increase in accessibility is derived from somewhat intricate probability calculations based on such assumptions as the average duration of a call, and the calling rate, and probably would not, in any particular case, fit the figures given in the illustration. These are arbitrarily picked merely to bring out the possible reduction in selectors due to the effect of chance distribution and greater accessibility.

In this example only the matter of mutual accessibility has been mentioned; the method of obtaining this accessibility in practice has not been brought in. Actually there are two methods in general use as has already been indicated: by line switches, or by line finders. It was natural that the line switch should have been developed first because it accomplished a considerable reduction in the number of selectors with a simple mechanism and a minimum number of terminals over which hunting would have to be done. Without either line switches or line finders the ratio of selectors to lines is, of course, one hundred per cent, but the use of a line switch hunting over five trunks to selectors would reduce this figure, for example given in Figure 1, to twenty-five per cent. In this case a group of twenty lines would be arranged to be served by five selectors.

The reduction of selectors can be carried further, of course, by arranging the line switches so that they can hunt over a greater number of trunks. Based on the data of Figure 1, a line switch hunting over nineteen trunks would reduce the ratio of selectors to lines to nine and one-half per cent. The line switch method of obtaining accessibility, however, becomes expensive when it is attempted to obtain a large degree of accessibility. A switch is required for each line and every increase made in the number of trunks over which the switch will hunt means an increased cost which is multiplied by the number of lines. Development in the Bell System has been along the line of the alternative method of obtaining accessibility by use of a line finder. With this method the finding process is reversed; instead of

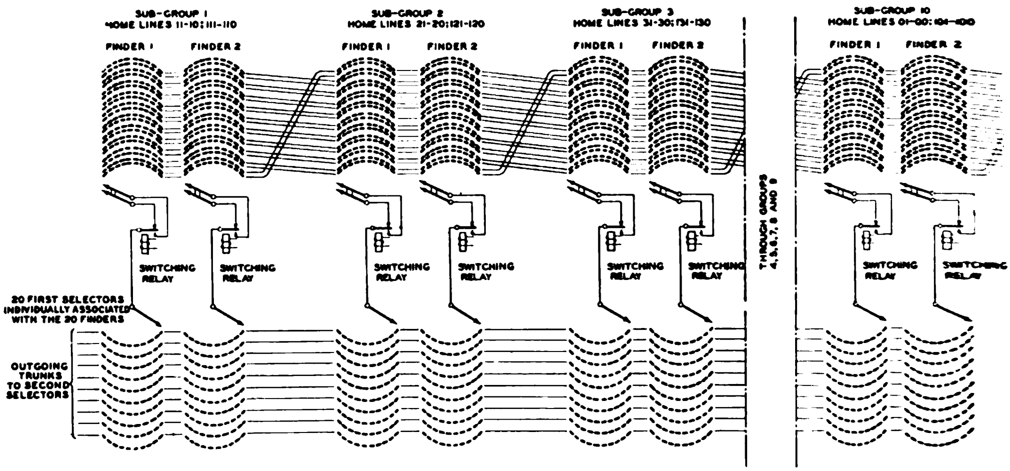


Fig. 3—Schematic arrangement of lines, line finders, and selectors for a unit of 200 subscribers

having the lines hunt for an idle selector, the selectors are made to search for the calling line. A line finder is provided for each selector so that each reduction in the number of selectors brings a like reduction in the number of line finders. This proves to be a more satisfactory way, from an operating standpoint, of solving the problem.

To obtain the same reduction in selectors, however, the wipers of a line finder must have access to many more contacts than those of the line switches. When the ratio of selectors to lines is twenty-five per cent, for example, each of the 250 line finders would require access to twenty lines whereas had line switches been used each of the thousand would have required access to only five trunks to selectors. It is desirable to have the hunting done between the instant the receiver is lifted from the hook and the time the subscriber is ready to dial so that the difficulty is not so much in actually hunting over a larger number of contacts as in accomplishing it in this short time. The manner in which this rather difficult feat is accomplished will be clearer after the line finder itself has been described.

As a basis for the step-by-step line finder there was available the standard step-by-step mechanism out of which the selectors and connectors are made. Its contacts are arranged in two banks, each having ten levels with ten contact positions arranged around a section of circular arc. A pair of wipers for each bank, by suitable relays and mechanisms, can be moved up one level at a time and then rotated around the arc to any one of the ten positions. The movement is always step-by-step, that is, up one level at a time or around one contact position at a time, which gives the name to the complete system of switching.

As it was originally used this switch had access to one hundred lines. Four contacts were available for each line, the two banks each of one hundred pairs of contacts just making up this number. In the more recent systems each line requires only three contacts so that by adding a third bank to the switch six hundred contacts, or two hundred lines, become available. An

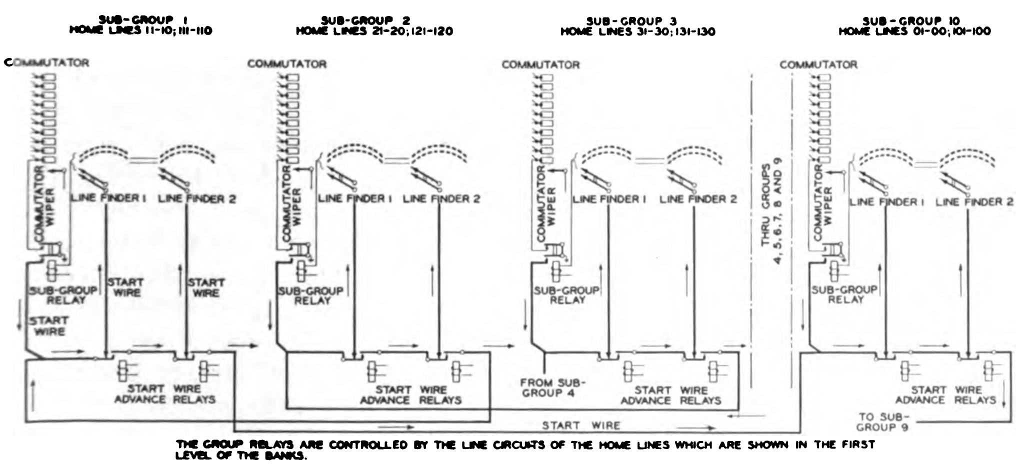


Fig. 4—Schematic arrangement of sub-group relays, commutators, and start wires

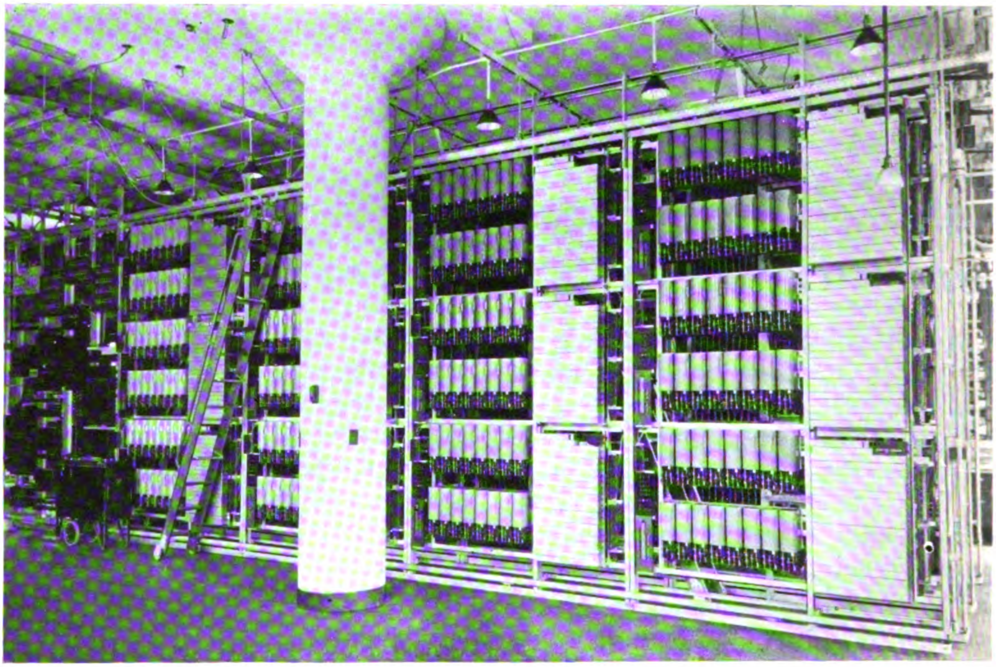


Fig. 5—Line-finder frames in a central office. Each group of two hundred lines has only sixteen line finders associated with it

accessibility of two hundred lines was deemed sufficient to reduce the number of selectors to a satisfactory total and the switch thus developed is shown in Figure 2.

Although this switch gives access to two hundred lines there are only one hundred stopping positions of the brush, ten rotational positions on each of the ten levels. Which line is chosen of the two that terminate in each position depends on the action of relays associated with the switch. If one of the pair of lines running to a brush position were in use and a call should come in on the other, another of the finders serving that group would "hunt" for it, as the two hundred lines running to any finder are multipled to each of the other finders serving that particular two hundred lines.

In order to hold the average hunting time of the finder to a minimum each group of two hundred lines is divided into ten sub-groups of twenty lines, and each of these sub-groups appears on the lowest level of one or more of the line-finder banks, and constitutes the "home lines" for these finders. This same sub-group of lines appears in the second level of another set of line finders, in the third level of another set, and so on. The line finder "start" circuit is so arranged that when a call originates, one of the line finders that has the calling line among its "home lines" begins to hunt for it. If these particular finders were busy the start lead would be transferred to the finders having the calling line in their second level, and if these in turn were busy, to the finders with the line in their third level, and so on. In this way minimum hunting time is required for each call. The manner in which the lines are mul-

tipled to the different finders and the way in which the start lead is transferred from one to another may be understood by a study of Figures 3 and 4.

These two-hundred-point line finders, a typical installation of which is shown in Figure 5, have now been in use for some time. In the installation illustrated, three groups of finders, each group serving two hundred lines, are mounted in a vertical frame. The line and cut-off relays are arranged at the right of the line finders.

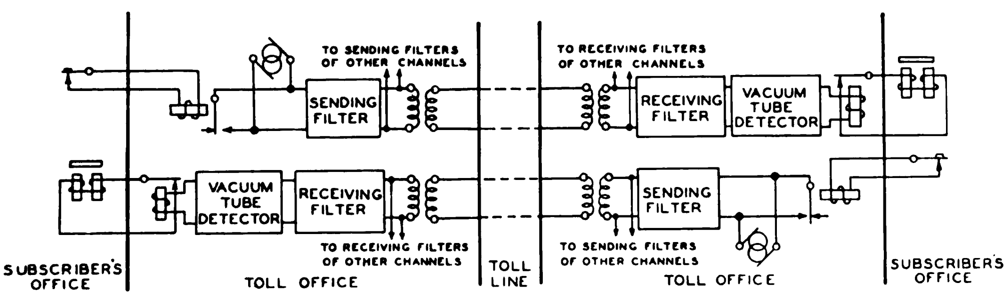
The development of the line finder to replace the line switches illustrates a trend, noticeable in other Bell System developments of dial apparatus, to replace a large number of small mechanisms by a smaller number of more inclusive ones. This results in fewer pieces of equipment to maintain and opens the way to still better service to the subscriber.

New Equipment for Voice-Frequency Telegraphy

By J. A. MAHONEY
Systems Development Department

ONE of the telegraph systems being used to a steadily increasing degree on Bell System lines is that which provides facilities for transmitting, over a four-wire circuit, twelve messages simultaneously in each direction by means of currents in the voice-frequency range. It is used almost entirely for "leased wire" service between subscribers in distant cities who, employing their own operators, have the channels available for continuous service. A simplified form of the necessary apparatus is now available, retaining the electrical characteristics of the older assembly but introducing an improvement in compactness and convenience.

By the use of carrier currents in a frequency range approximating that of the voice currents of telephone conversations, the system has been made suitable for a toll plant designed primarily for telephone transmission. At intermediate points the complex current conveying all the telegraph messages is amplified by ordinary



Carrier-telegraph apparatus for a single two-way channel, connected to a toll line

four-wire telephone repeaters. The essential elements of the system are a generator for producing the carrier currents; relays for controlling their transmission in accordance with a telegraph code; filters for separating the different frequencies, combined for transmission over the line; and vacuum-tubes for rectifying each of the separated alternating currents into direct current for operating the telegraph receiving apparatus. Terminal apparatus embodying these

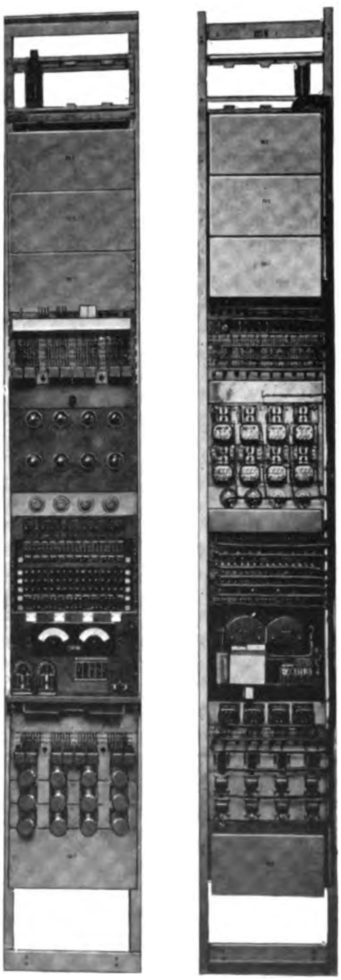


Fig. 1—Front and rear views of the new bay, containing four channel terminals.

units, connected at each end of a toll line, make it a path for telegraph messages rather than for conversations.

For each of the two-way channels, and so for the current of each frequency, a group of apparatus known as a channel terminal is provided at each terminal office, to translate between the alternating-current line signals and the direct-current impulses of the subscriber's sending and receiving apparatus. The group of terminals associated for service over the same toll line, twelve or less in number, make up a system terminal.

In the schematic the circuit arrangement is shown. Operation of a subscriber's key, or automatic transmitter, controls direct current through the windings of the sending relay, which in turn controls the alternating current passing onto the line. During spacing signals this relay short-circuits the alternating current, and during marking signals allows it to flow through the sending filter to the line. At the incoming end, the receiving filter of each channel terminal selects the proper current, which is amplified and rectified by the vacuum tubes of the detector circuit. The rectified current operates the receiving relay, which in turn controls the receiving subscriber's sounder or printer.

While messages are passing in one direction on one pair of the toll circuit, other messages are going in the opposite direction over the other pair. A subscriber wanting simultaneous service in both directions has two circuits between his establishment and the toll office. That arrangement, known as "full duplex" operation, is the one shown on the circuit sketch. For "half duplex" service, in which messages in opposite directions may

be sent as desired, but not simultaneously, only one circuit is required between the subscriber's premises and the toll office, but a one-way carrier channel is needed in each direction.

An important operating feature of the terminal equipment is the provision made for monitoring. An attendant at the central office must be able to observe operation of the circuits to be sure that everything is in good order, and must communicate with the subscribers' operators from time to time, in emergencies as well as about routine matters. The circuit sketch shows the sounders and meters by which operation can be observed, and the telegraph key by which the attendant can take control of the circuit. It is important that the monitoring apparatus be as convenient as possible, since many of the telegraph channels are used by financial houses in whose service interruptions or delays might be costly. Following then-current telegraph practice, the original voice-frequency equipment had monitoring apparatus permanently connected to each channel terminal, although it was not possible for the attendants to give their oversight to more than a few repeaters at a time. Since experience has shown that adequate supervision can be maintained with fewer sets of monitoring apparatus, in the new form of equipment only one set has been provided for each four channel terminals.

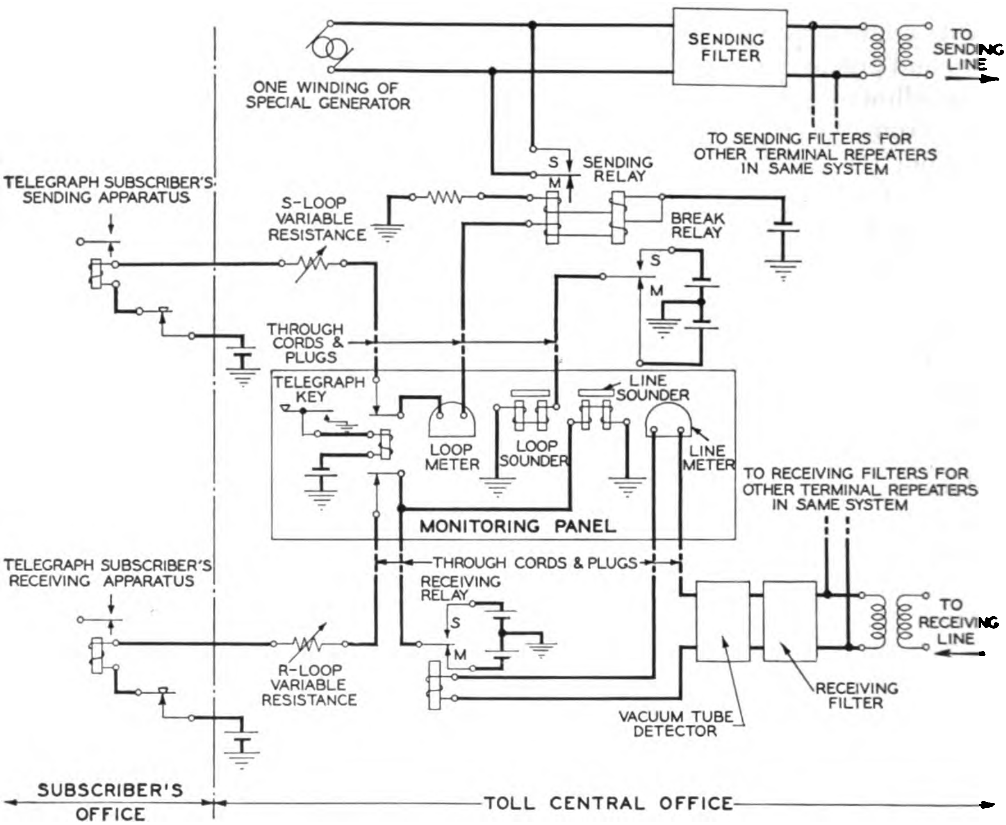
This use of common monitoring equipment, connected into any circuit at will by jacks, plugs and cords, has been greatly facilitated by the convenient location of the apparatus involved. It will be noted from the photographs that like pieces of apparatus have been grouped on mounting plates especially designed for them. At the top of each bay are plates bearing retardation coils, condensers, resistances and other minor elements normally requiring no attention; the telegraph relays, which need occasional maintenance, are located near the bottom; and the central portion of the bay is left clear for the apparatus used in controlling the repeaters. An improvement is thus realized over the method of mounting both fixed and adjustable apparatus for a particular circuit on one panel,



Fig. 2—Two bays of panel-mounted terminal equipment, equivalent to a single bay new equipment

which of course could not be located at the most convenient part of the bay for all the circuits.

Mounting most of the apparatus on standard mounting plates has made the bay rather than the panel graph relays and the receiving potentiometers, there are exactly four units of apparatus, one for each of the channel terminals. Where there are several units for each circuit on one of the plates, as in the case of the



A channel terminal and associated subscriber's apparatus arranged for full duplex operation and with the monitoring panel connected

the unit of equipment. Apparatus for four channel terminals and one monitoring panel are normally assembled on a channel-iron rack, and are wired in a single local cable. In contrast, the older panel-mounted equipment required a complete bay for two channel terminals and the two monitoring panels associated with them. On many of the mounting plates in the new bays, such as those for the tele-resistances and keys, these have been arranged in four separate groups. The only exception to the sub-grouping on the mounting plates, aside from the monitoring panel, is the filters; each of these is assembled complete on an individual plate. As a result the bay is divided in a general way into four vertical groups, each constituting a channel terminal. Ordinarily the bays will be lined up in

groups of three, the number required for twelve channels in each direction.

The advantages of this type of mounting are apparent in Figure 1. Any particular piece of apparatus is located in the same position in the bay for every repeater, a feature especially important for the circuit elements requiring attention—the jacks, keys and potentiometers. Convenience also follows on the wiring side of the bays from the arrangement, as well as from the accessibility of the terminals of all the apparatus.

Along with the improved assembly, simpler types of apparatus have been introduced. In the older terminal repeater, an expensive forty-step rheostat was used for the variable resistance in series with the subscriber's loop. This has been replaced by a series of flat-type resistances having values of fifty ohms, one hundred ohms, two hundred ohms, and so on up to eight hundred ohms, each of which can be short-circuited by a push-button key. Any value of resistance from fifty ohms to the total can be secured, in steps of fifty ohms, by operation of the proper combination of keys, with five or six resistances taking the place of the forty used in the rheostat. The key combination is a little less convenient to adjust, but since the adjustment is changed only when the repeater is connected to a new subscriber, this disadvantage is slight, and is more than offset by the greater ruggedness and reliability of the newer, simpler apparatus.

In the Bell System plant, voice-frequency telegraph systems are in use along the main toll cables, with a total of about 170,000 miles of two-way channels in operation on October 1, 1928. There were at that time thirty-three systems in service, the longest being from New York to Chicago, a distance of 884 miles. These systems form a network together with the open-wire high-frequency telegraph systems, which touches almost every important city in the country, and is an important factor in maintaining the highest grade of telegraph service now offered—telephone typewriter service at sixty words per minute in each direction. Combining the advantages of reliability and simplicity with savings in first cost and floor space, the new equipment will promote further the use of such facilities, thereby helping to secure the most productive use of the toll cables.

Ringing Machines for Small Offices

By R. D. de KAY
Systems Development Department

THE problem of an economical source of ringing current for the smaller common-battery offices has brought a new type of ringing machine of such a capacity that it will take its place between the two types already in use. In one type of these present machines, used principally in the smallest offices and in private branch exchanges, battery current is converted into alternating current for ringing by a vibrating-reed interrupter and a transformer. Although this apparatus is satisfactory at the switchboards for which it is intended, by its nature it does not regulate voltage closely enough for offices presenting a greater variety of ringing conditions. It is intended for switchboards at which ringing is controlled manually and at which busy signals and other information are given by voice, rather than by signal tone. No provision is made, therefore, for intermittent current for machine ringing, or for signal tones.

Where requirements call for interrupted currents and tones for signalling, and for ringing current controlled by the machine rather than by the operators, a ringing machine of the other type — Type P — has been used. In this, a motor driven alternator furnishes twenty-cycle voltage and rotating drums interrupt the ringing and signalling currents as required. The capacities of these machines, ranging from one to eight amperes, make them adequate for the largest offices, and their output voltage and frequency, which are controlled by regulators, are sufficiently close for the most severe conditions. For the smaller offices using machine ringing, however, certain of the properties of these ringing generators have not been needed. Regulation is considerably closer than is necessary in many such offices, and the current output of the smallest Type P machine exceeds requirements of maximum traffic by a substantial margin.

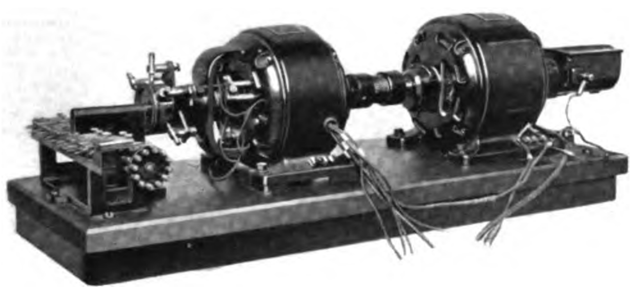
The new machines have therefore been designed to embody only those features useful in offices with a busy-hour traffic of three thousand calls or less. A small twenty-cycle motor-generator set was selected, and high-speed interrupters were added for busy and other tones, a commutator for pulsating current, and low-speed interrupters to make possible the connections needed for machine ringing. The generator has a capacity of a half ampere, delivered at 72 to 88 volts. No voltage regulator on the output has been provided. In the case of the battery-driven sets for which the input voltage may vary between twenty and twenty-eight, a centrifugal regulator has been provided to hold the speed between 1100 and 1200 revolutions per minute. The generator voltage is held within sufficiently close limits by additional field windings in series with the mo-

tor armature. Neither the regulator nor the compound winding will be required for machines to be driven by central-station power.

On the generator shaft are two slip-rings and a ring for delivering pulsating current. Tones of 480 and 160 interruptions per second are secured by a brass drum on an extension of the generator shaft; one brush feeds direct current to the drum, and two pairs of collecting brushes pick up the interrupted currents. The low-speed interrupter, at the end of the machine, is driven by a worm-gear. Instead of another drum with intermittent insulated areas in the path of the brushes, there is a group of rotating discs which bear rollers near their circumferences. During rotation each set of rollers operates a group of flat contact springs, similar to the spring pileup of a key or a relay, which make and break contact 60 or 120 times per minute for signalling current, or connect and disconnect ringing current at the standard ringing intervals. No provision has been made for current to collect and return coins, but that can be supplied readily in these small offices, by a bank of dry cells or otherwise.

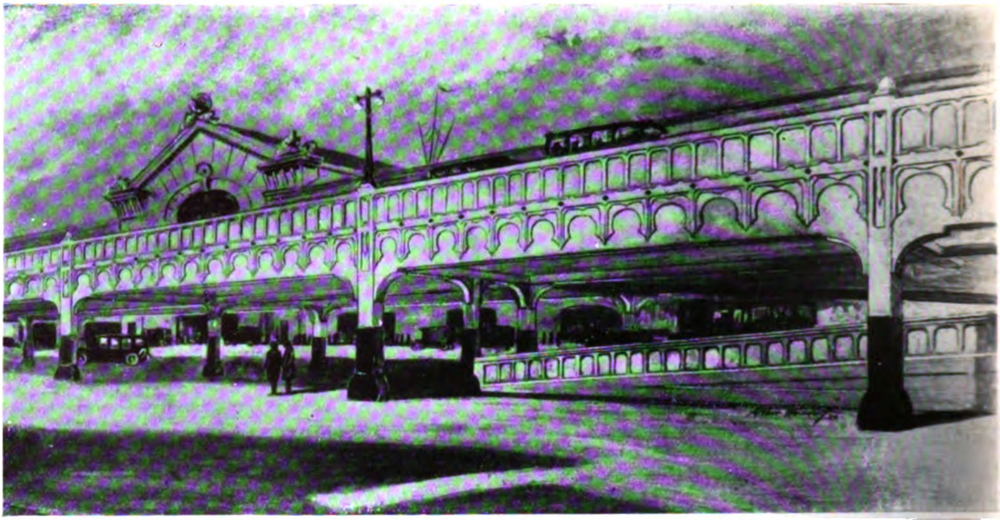
An autotransformer, not shown in the picture, is provided for P. B. X. and toll ringing current, and for districts where the subscribers' ringers require slightly different voltages. It is also used when the voltage is near the lower limit to step it up for testing the tripping relays. When the voltage rises, a relay switches the testing circuit to the generator terminals.

The whole set, except for the transformer, is mounted on a slate slab which in turn is screwed onto a wooden base. One machine is adequate in capacity, but two will ordinarily be provided to insure continuous service. The light weight and compactness of the sets make it possible to mount them on a pipe framework, one above the other; the floor space needed is thus reduced to less than half of that occupied by two type P ringing machines.



The new ringing machine, mounted on its slate and wood base. The motor-speed regulator is at the extreme right

Economy is not restricted to floor space, however; two of the sets cost less than half as much as two of the type P sets which would otherwise be needed for an office. The resulting reduction in the power-plant cost will have a tendency to extend the application of machine ringing in the smaller offices.



West Side Motor Highway

Members of the Laboratories are naturally attentive to civic enterprises affecting the convenience of transportation to and from 463 West Street and the appearance of its environs. West-side improvement projects have been under discussion for some time and have taken many forms. The Board of Estimate of the City of New York has recently approved plans for an elevated express motor highway along the west side of the city.

The highway will extend from Canal Street to Seventy-second Street. Consisting of two roadways, each thirty feet in width, it will provide for three lines of traffic in each direction. Sets of ramps about a mile apart will furnish access to the highway at points other than its termini. Four ramps with ten-foot roadways will compose each set, affording ascent and descent to uptown and downtown traffic. From Canal Street to Fifty-ninth Street the highway will be supported on sets of three columns. The sets will be about sixty feet apart, except where the highway spans cross-streets, and the columns of each will be thirty-four feet apart.

Proceeding along West Street, the highway will pass about seventy feet west of the front of our building. The nearest set of ramps will be somewhat south of Twenty-third Street; the picture above shows the anticipated highway at that point. Ending conveniently near the Holland Tunnel, and connecting with the Hudson River Bridge, the highway will yet further facilitate automobile passage between the Laboratories and New Jersey.

The section from Canal Street to Fifty-ninth Street will cost about $16,000,000 and will be financed by assessment on the taxpayers of the Borough of Manhattan. It is expected that work on this section will begin in a month or two and will continue for about three years.

Service Honors for 1928

MORE THAN THIRTY YEARS



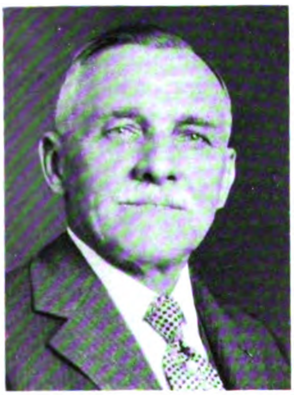
Arthur E. Peterson
Research Department
Thirty-five years



Wilton L. Richards
Consulting Historian
Fifty years



Arnold S. Bertels
Systems Development
Forty years



Conrad Schaul
Development Shop
Thirty-five years



John F. Toomey
Systems Development
Thirty-five years



THIRTY YEARS

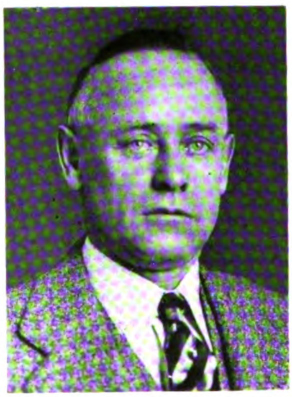


Adolph Bregartner
Systems Development

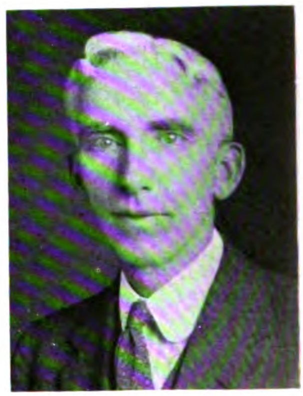
Frederick E. Anderson
Systems Development



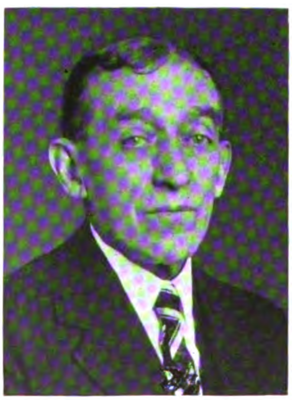
Goodwin Rosenblum
Development Shop



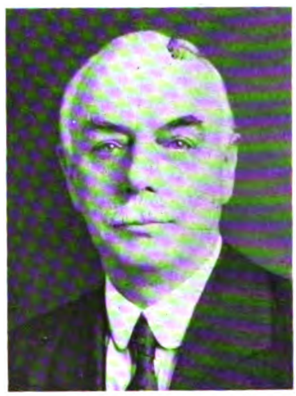
Albert J. Ketschke
Research Department



William McA. Smith
Systems Development



Edward J. Harrington
Development Shop



George Thompson
Systems Development

TWENTY-FIVE YEARS



John J. Lohrey
Development Shop



Lee R. Laird
General Staff



Adolph Sulzmann
Research Department



Charles Borgmann
Manual Equipment Engineer



George Hatcher
Plant Operation



George Hess
Plant Construction



Sergius P. Grace
Assistant Vice-President

TWENTY-FIVE YEARS



Roy R. Ireland
Specifications Engineer
Apparatus Development



Joseph Irish
Systems Development



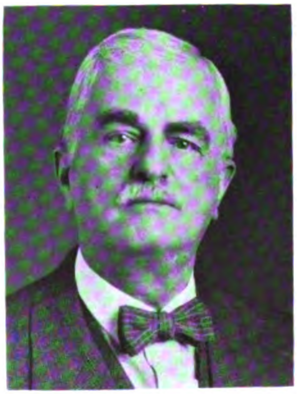
Anthony Verrastro
Plant Construction



Arthur K. Forsyth
Apparatus Development



George Dodd
Apparatus Development



George F. Morrison
Power Engineer
Plant Operation



Charles H. Klein
Apparatus Development

News Notes

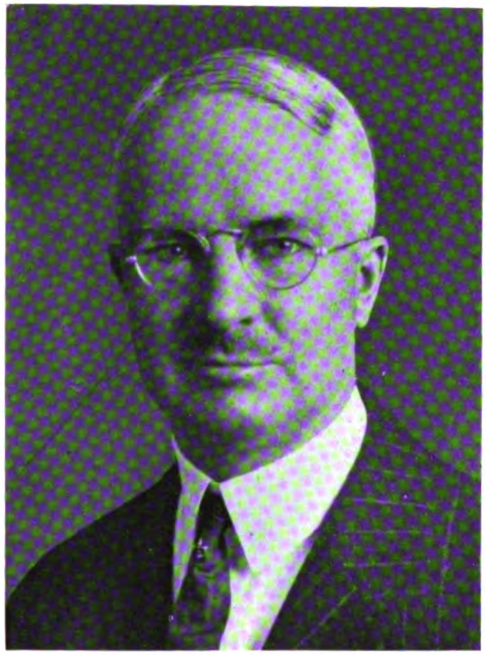
DR. JEWETT attended an assembly luncheon of the Boston Chamber of Commerce at Boston on January 10 and spoke on "The Romance of Research in the Telephone Industry."

ON DECEMBER 29, Dr. Jewett contributed to a symposium on the "Organization of Scientific Research in Industry", at a meeting of the American Association for the Advancement of Science. His subject was "Finding and Encouragement of Competent Men."

J. E. MORAVEC has been appointed Assistant Vice-President in charge of Staff Department, effective January 14. His organization is as follows: J. W. Farrell, Secretary and General Attorney, in charge of the Legal Department; W. B. Wallace, Treasurer, in charge of the Financial Department; E. J. Santry, General Auditor, in charge of General Accounting Department; B. B. Webb, Commercial Relations Manager, in charge of Commercial Relations Department; J. S. Hartnett, General Service Manager, in charge of the General Service Department; W. B. Sanford, Plant and Shops Manager, in charge of Plant and Shops Department.

R. B. BONNEY, Educational Director of the Mountain States Telephone and Telegraph Company, was a guest of the Laboratories January 2 to 16 for an extended inspection of the facilities here and for observation of current developments. On account of his interest in college relations work, he wanted, among other objectives, a general picture of the Laboratories as a research organization, and information on studies now in progress.

AT THE JANUARY 7 MEETING of the Colloquium, J. A. Becker spoke on "The Science of Coated Filaments". On January 21, J. E. Harris spoke on "Application of the Phase Rule to Metallurgical Problems".



R. B. BONNEY

THE ACOUSTICAL SOCIETY OF AMERICA was formed at a meeting held here on December 27, for the purpose of bringing together workers in all branches of pure and applied acoustics. Among its activities will be the provision of a medium of publication for papers on acoustics, for

which there is acute need; such papers have hitherto been widely scattered.

Elected to temporary office were: President—Harvey Fletcher of the Laboratories; Vice-President—Professor V. O. Knudsen of the University of California; Secretary—Wallace Waterfall of the Celotex Company; Treasurer—C. F. Stoddard of the American Piano Company. A committee was appointed by Dr. Fletcher to consider the details of organization, and the first regular meeting will take place here some time in April. There were present forty of the leading authorities on acoustics, among whom were Professor D. C. Miller of the Case School of Applied Science, Professor F. A. Saunders of Harvard University, J. P. Maxfield of the Victor Talking Machine Company, R. V. Parsons of the Johns Manville Company, and Professor F. R. Watson of the University of Illinois. After the meeting, Dr. Arnold entertained the members at luncheon.

Inspection Engineering

J. A. St. Clair, San Francisco



Members of the Acoustical Society of America: left to right: back row: W. P. Mason, B.T.L.; J. C. Steinberg, B.T.L.; V. L. Chrisler, Bureau of Standards; E. J. Schroeter, Macoustic Eng. Co.; E. C. Wente, B.T.L.; W. C. Jones, B.T.L.; second row from back: L. J. Sivian, B.T.L.; E. L. Norton, B.T.L.; W. A. MacNair, Victor Co.; R. F. Mallina, Victor Co.; Lonsdale Green, Jr., Johns-Manville Corp.; R. H. Schroeter, Macoustic Eng. Co.; H. W. Lamson, Gen. Radio Co.; C. N. Hickman, American Piano Co.; D. G. Blattner, B.T.L.; second row from front: H. A. Erf, Northern Ohio Tel. Co.; H. C. Harrison, B.T.L.; J. B. Kelly, B.T.L.; R. L. Wegel, B.T.L.; H. A. Frederick, B.T.L.; N. R. French, A. T. & T.; C. W. Hewlett, G. E. Co.; A. T. Jones, Smith College; Irving Wolff, R.C.A.; J. B. Taylor, G. E. Co.; front row: F. A. Saunders, Harvard U.; R. V. Parsons, Johns-Manville Corp.; D. C. Miller, Case School of Applied Science; Wallace Waterfall, Celotex Co.; V. O. Knudsen, U. of California; H. Fletcher, B.T.L.; C. F. Stoddard, American Piano Co.; J. P. Maxfield, Victor Co.; F. R. Watson, U. of Illinois; F. K. Richtmeyer, Cornell U.; G. R. Anderson, U. of Toronto

Field Engineer, visited Seattle, Tacoma, Portland and other cities in Washington and Oregon during the second week in December in connection with Field Engineering duties.

A. F. GILSON AND P. S. OLMSTEAD attended a regular survey conference on telephone receivers at Hawthorne during the latter part of December.

W. A. BOYD, in company with a committee for the study of protective metal finishes, visited Norfolk, Atlanta, Birmingham and New Orleans during the early part of January.

A. G. DALTON AND R. J. NOSSAMAN visited Philadelphia during the latter part of December in connection with Field Engineering work.

H. F. DODGE was the author of an article "Using Inspection Data to Control Quality", which appeared in MANUFACTURING INDUSTRIES for November and December.

RESEARCH

E. F. KINGSBURY addressed the Women's Club of Rutherford, New Jersey, on television on January 7.

AMONG PAPERS presented before the American Physical Society at its midwinter meeting at Columbia University were "The Maximum Excursion of the Photoelectric Long Wave Limit of the Alkali Metals", by H. E. Ives, read on December 27, and "A Wave Mechanism of Quantum Phenomena" by R. V. L. Hartley, on December 29. On the latter date, a paper "Anomalous Dispersion of Electron Waves by Nickel", by C. J. Davisson and L. H. Germer, was also given.

T. C. FRY was one of the presiding officers of a joint meeting of the Mathematical and Physical Societies.

H. A. FREDERICK attended a meeting of a committee of the National Research Council on "Substitutes for Sound" at St. Louis on December 8.

GEORGE KNAPP gave an illustrated talk on television at the Columbian Club at Elizabeth, New Jersey.

A. W. HAYES worked on handsets at Hawthorne recently.

G. R. YENZER was at Hawthorne on December 10 in connection with resistance requirements for condenser transmitters.

R. M. BURNS inspected some instances of corrosion in central offices at Atlantic City on December 3 and 4.

B. L. CLARKE made a survey of lubrication problems at Hawthorne and visited centers of lubrication research at Washington, Minneapolis, Madison and Pittsburgh.

C. L. HIPPENSTEEL AND C. W. BORGMANN discussed corrosion problems with engineers of the New Jersey Zinc Company at Palmerton, Pennsylvania.

A. R. KEMP visited the Columbian Rope Company at Auburn, New York, in regard to cable developments.

R. L. PEEK attended the Plasticity Symposium held at Lafayette College in Easton, Pennsylvania.

R. M. BURNS AND D. J. SALLEY attended the Soil Corrosion Conference at the Bureau of Standards at Washington and made experimental investigation of protective coatings at Hawthorne, from December 9 to 29.

HARVEY FLETCHER attended committee meetings on research for the deaf at Washington, D. C., in connection with the Anthropology and Psychology Division of the National Research Council.

R. O. MERCNER visited the Vibration Specialty Company at Philadelphia on December 15 to observe the balancing of high-speed machines.

E. C. WENTE's article, "Speech Interpretation in Auditoriums", which appeared in the RECORD for October, has been reprinted in the December issue of the Gamma Alpha Record.

H. ECKHARDT made phonograph records at Houlton, Maine, of transatlantic conversations between Austin Bailey of the Long Lines Department at 24 Walker Street, and Colonel Shreeve, at London, on January 7 and 8. Simultaneously, E. Peterson recorded these conversations at the Laboratories.

OUTSIDE PLANT DEVELOPMENT

C. S. GORDON visited the New York Insulated Wire Company at Wallingford, Connecticut, on December 6 in connection with the preparation of trial lots of drop wire.

E. M. HONAN was in Boston to discuss with members of the Simplex Wire and Cable Company problems dealing with the manufacture of rubber-insulated wire.

C. D. HOCKER AND F. F. FARNSWORTH visited several of the associated telephone companies in the middle west, as well as the plants of several automobile body manufacturers and paint companies, to investigate paint finishes for automotive equipment.

C. Q. LUMSDEN was engaged in studies of chestnut poles at Shipman, Natural Bridge and Waynesboro, Virginia, from December 20 to 22.

GENERAL STAFF

M. B. LONG addressed the Philadelphia Section of the A. I. E. E. on January 14, on the subject of the photoelectric cell and its use in communication. Prior to the meeting, Mr. Long was the guest of the Engineers Club at dinner.

JOHN MILLS spoke on "Electrical Eyes and Their Use in Communication" before the Engineers Club of St. Louis on January 9, the Southwestern Bell Telephone Company employees on January 10, and on January 11, he addressed the engineering students of Washington University. The following day, Mr. Mills spoke on the same subject before the Round Table of the University.

S. P. GRACE addressed the staff of the Carson Peck Memorial Hospital in Brooklyn on January 10, on recent developments of the Laboratories. Mr. Grace also lectured before the Engineers Club of Cincinnati.

T. W. CLARKE has been elected to membership in the Edward J. Hall Chapter of the Telephone Pioneers.

HELEN O. LUEDTKE, a stenographer in the Transcription Department, died on Friday, January 4. Miss Luedtke had been a member of the Laboratories since February, 1926.

H. M. ANDERSON, a shop mechanic in the Plant and Shops Department, died on December 14. Mr. Anderson had been associated with the Laboratories since March 6, 1918.

PATENT

MEMBERS OF THE PATENT DEPARTMENT who went to Washington during the period from December 11 to January 10, in connection with the prosecution of patents were: E. W. Adams, W. C. Kiesel, I. MacDonald, T. P. Neville, J. W. Schmeid and G. H. Stevenson.

APPARATUS DEVELOPMENT

F. F. LUCAS spoke on metallography before the American Society for Steel Treating at Buffalo.

S. J. ZAMMATARO's article, "Development of the Impedance Bridge," which appeared in the RECORD for December, has been reprinted in full

in the January issue of the Sibley Journal of Engineering.

J. R. TOWNSEND's article, "New Specifications for Raw Materials," which appeared in the RECORD for February, 1928, has been reprinted in the December issue of "Instruments."

E. T. MOTTRAM tested film recording machines at Hawthorne.

O. L. WALTER discussed suggested changes in the 202-B reproducer set at Hawthorne.

J. C. HERBER's article, "Frequency Control for Broadcasting", which appeared in the RECORD for September, has been reprinted in the November issue of the Bent of Tau Beta Pi.

S. J. ZAMMATARO AND T. SLONCZEWSKI visited the Leeds and Northrup Company at Philadelphia to inspect shielded-type precision bridges.

H. BROADWELL attended conferences at Hawthorne on the manufacture of precision interrupters.

F. H. HIBBARD visited Chattanooga, Tennessee, and Atlanta, Georgia, in connection with the revision of adjustment requirements on step-by-step relays.

SYSTEMS DEVELOPMENT

W. L. HEARD, as a member of the Standards Committee of the A. I. E. E., has participated in the preparation of graphical symbols for telephone and telegraph use. This work has now been completed, the symbols and abbreviations have been approved as an Institute standard and they are being transmitted to the American Standards Association.

E. H. SMITH spent a week at Chicago discussing step-by-step central-office equipment.

J. R. STONE AND H. L. MUELLER discussed exhaust equipment for pneumatic tube systems and various power machine problems with representatives of the General Electric factory in West Lynn, Massachusetts.

W. O. FULLERTON inspected at Rochester the new 506-A cordless P. B. X. being built by Stromberg-Carlson.

V. T. CALLAHAN discussed gas engine mufflers with members of the Maxim Silencer Company at Hartford, Connecticut.

E. J. KANE AND J. M. DUGUID investigated busy-tone wiring in the step-by-step office at Hartford.

G. E. BAILEY AND R. E. NOBLE recently inspected a new type of superstructure for frames and racks installed at Laurel Springs, New Jersey.

L. P. BARTHELD discussed cabling problems in the new Chicago Toll Office with Illinois Bell engineers.

C. ECKBERG is arranging for installation of improved radio broadcasting circuits at various repeater stations on the Pittsburgh-New York cable.

C. BORGMANN visited Boston, Chicago and Rochester in connection with equipment problems.

W. J. LACERTE visited Hartford and Atlantic City in connection with improved circuit arrangements for step-by-step central offices.

* * *

Two corrections should be noted in the RECORD for January.

On page 186, last paragraph, the number of regulators in the Long Lines plant should have been given as 41.

In the second paragraph on page 189 the second sentence should read "Under these conditions on a full size cable there is an IR drop along the cable of about *one* volt per hundred feet . . . "

Club Notes

During the month of March the Club will hold an indoor handball tournament at Labor Temple, Fourteenth Street and Second Avenue, Manhattan. Play will commence Tuesday evening, March 5, and matches will be held on Tuesday and



Thursday evenings from 5:30 to 7:30, for four weeks. The single-wall form of play will be used, and all games will be singles. The tournament will be conducted on an elimination basis, with all matches up to the semi-finals consisting of a single game. Semi-finals and finals will be decided by two games out of three. The winner will receive an order good for ten dollars' worth of merchandise at Alex. Taylor and Company, the second man, an order worth five dollars, and the two men eliminated in the semi-finals will each get an order worth two dollars and a half.

Entry blanks may be obtained from D. D. Haggerty, Room 164, and must be returned to him with the entry fee of twenty-five cents not later than Monday, February 25. Before each round, players will be advised of date, time and opponents with whom they have been matched.

Indoor Golf

Plans have been completed for the final tournament of the indoor golf season, which will be played on Wednesday evening, February 27, at the Miniature Golf Course of America, 41 East 42nd Street, Manhattan.

As in previous tournaments all contestants will play thirty-six holes of medal play in the qualifying round after which they will be divided into two groups of four flights each with prizes for the winner in each of the eight flights. Sixty-four players will be qualified for the finals.

Entries should be forwarded to D. D. Haggerty, and accompanied by an entrance fee of $1.50.

In addition to the prizes supplied



by the Club, a valuable prize will be donated by the management of the golf course.

Photographic Contest

The annual Photographic Contest, open to all the members of the Laboratories, is now under way. Entries

should reach D. D. Haggerty before March 1, after which date they will be exhibited and judged. Prints are to be divided into four classes: portraits, landscapes, still life and colored transparency. For further information regarding rules and prizes, call Margaret Horne, Extension 786, or D. D. Haggerty, Extension 542.

Glee Club

It is the wish of the music committee that every department of the Laboratories be represented in the Glee Club. The active membership may be divided as follows: Systems Development, 12; Patent, 11; Apparatus Development, 6; Research, 5; Accounting, 2; Inspection, 1.

Trained voices are not necessary, but a fairly good voice and some ability to read music are desirable. The Glee Club is now rehearsing for a formal recital to be held in April as a part of the Spring Dance and Entertainment of the Club. For that reason, new members will not be accepted after March 1. Meetings are held every Wednesday evening from 5:10 P. M. to 6:10 P. M. in the Women's Rest Room on the eleventh floor. For further information call either Ada Van Riper or P. H. Betts.

Bridge

The men's bridge club recently completed its ten-week tournament and on Monday, January 7, and Monday, January 14, sixty men took part in an elimination tournament to determine who would represent the Club in the annual tournament with the Western Electric Bridge Club. This match will be held on Monday evening, March 4, at 195 Broadway, and forty players from each company will compete for the trophy, now held by the players from Western Electric.

A second tournament of ten weeks' duration was started by the members of the Club on Monday evening,



January 28. This group meets each Monday evening in Rooms 275 and 277 and the committee in charge is always glad to welcome new players.

The women's bridge club played the first game of the mid-winter tournament on Friday, January 5th. The tournament will continue for ten weeks and in order to be eligible for tournament prizes players must take part in at least seven out of the ten games.

The bridge club conducts a meeting every week, at which prizes are given for high scores. Those interested may apply to Mary V. Lynch.

Symphony Orchestra

Until further notice the orchestra, which formerly met on Thursday evenings, will meet on Tuesdays at 5:05 in the Women's Rest Room. A buffet supper will be served by the restaurant management in the Rest Room at 5:45.

The orchestra, for a time under the leadership of Mr. Egon Eibert, a professional conductor, is again being conducted by L. E. Melhuish. Mr. Melhuish stresses the fact that, although regular attendance at rehearsals is desirable, the program for the remainder of the season has been so arranged as to make it interesting for those who cannot attend each of

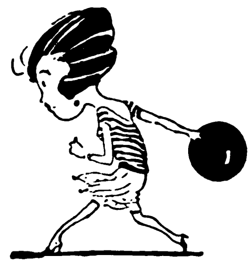
the weekly meetings of the orchestra.

A class of music suitable to the number attending rehearsals will be undertaken. Members are encouraged to suggest selections for rehearsals, which the club in turn will be glad to procure. The repertoire now consists of standard overtures, operatic selections, symphonies and popular selections from musical comedies.

Women's Bowling

The second half of the bowling season begins with a reorganization of the women's bowling group under the supervision of a committee of men, appointed by the General Chairman of the men's bowling league. This committee is looking after the interests of the women bowlers, with a view to promoting an enthusiastic and successful season.

Arrangements may be made



through Antoinette Kelly or Marian Kane to have one's name placed on the substitute list.

With the close of the bowling season, a dinner and theatre party will be given to the bowlers. At dinner, prizes will be awarded to the winners.

Club Calendar for February

FRIDAY, 1: Basketball, Men, Bell System League Tournament, Stuyvesant High School, 8.30
Bowling, Dwyers Manhattan Alleys, 5:45
Bridge, Women, Rest Room, 5:10

SATURDAY, 2: Chess Match, Commercial Chess League, New York Edison Co.

MONDAY, 4: Basketball, Men, Bell System League Tournament, Stuyvesant High School, 8:30
Basketball, Women, St. Luke's gymnasium, 5:30
Bridge, Men, Room 275, 6:00

TUESDAY, 5: Basketball, Men, Interdepartmental League Tournament, Labor Temple, 5:30
Orchestra, Rest Room, 5:05

WEDNESDAY, 6: Basketball, Men and Women, Bell System League, Erasmus High School, 7:30
Glee Club, Rest Room, 5:05
Swimming Class, Women, Carroll Club, 5:30
Club Dance, Hotel St. George.

THURSDAY, 7: Basketball, Men, Interdepartmental League Tournament, Labor Temple, 5:30

FRIDAY, 8: Basketball, Men, Bell League, Stuyvesant H. S., 8:30
Bowling, 5:45
Bridge, Women, Rest Room, 5:10

MONDAY, 11: Basketball, Men, Bell League, Stuyvesant H. S., 8:30
Basketball, Women, St. Luke's gymnasium, 5:30

WEDNESDAY, 13: Basketball, Men and Women, Bell System League, Erasmus Hall H. S., 7:30
Glee Club Rehearsal, 5:05
Swimming Class, Women, 5:30

THURSDAY, 14: Basketball, Men, Interdepartmental League Tournament, Labor Temple, 5:30

FRIDAY, 15: Basketball, Men, Bell League, Stuyvesant H. S., 8:30
Bowling, 5:45
Bridge, Women, Rest Room, 5:10

SATURDAY, 16: Chess Match, Commercial Chess League, Guaranty Trust Co.

MONDAY, 18: Basketball, Men, Bell League, Stuyvesant H. S., 8:30
Basketball, Women, St. Luke's gymnasium, 5:30
Bridge, Men, Room 275, 6:00

TUESDAY, 19: Basketball, Men, Interdepartmental League Tournament, Labor Temple, 5:30
Orchestra Rehearsal, 5:05

WEDNESDAY, 20: Glee Club, 5:05
Swimming Class, Women, 5:30

THURSDAY, 21: Basketball, Men, Interdepartmental League Tournament, Labor Temple, 5:30

MONDAY, 25: Basketball, Men, Bell League, Stuyvesant H. S., 8:30
Basketball, Women, St. Luke's gymnasium, 5:30
Bridge, Men, Room 275, 6:00

TUESDAY, 26: Basketball, Men, Interdepartmental League Tournament, Labor Temple, 5:30
Orchestra Rehearsal, 5:05

WEDNESDAY, 27: Glee Club, 5:05
Swimming Class, Women, 5:30

THURSDAY, 28: Basketball, Men, Interdepartmental League Tournament, Labor Temple, 5:30

BELL LABORATORIES RECORD

LEADERSHIP IN INDUSTRIAL RESEARCH

By Frank B. Jewett

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A NEW TELEPHONE DOORWAY

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Leadership In Industrial Research

By FRANK B. JEWETT

Excerpts from an address before the symposium on organization of scientific research in industry, held as a part of the New York meeting of the American Association for the Advancement of Science, December 29, 1928

TWENTY-FIVE years of doing, finding and encouraging others to do scientific research in industry, and of organizing the machinery for the smooth and effective conduct of such research, have left me with a feeling that so far as this branch of human activity is concerned the problems in essence are not materially different from those met elsewhere. Years ago, in a less mature period of life, I may have thought that the effective industrial research man was a being somewhat different from his fellow workers in adjacent fields. I may have thought that some peculiar slant of mind, some slightly different outlook on life, or some special appraisement of relative values branded him with a distinguishing hallmark that designated him unescapably for special treatment and special relationship in the industrial environment.

If such ideas were ever mine, I have long since outgrown them. My present view is that except in those details which are the direct consequence of a particular function, the problem of finding and encouraging competent men in industrial research is in no substantial measure different from the finding and encouragement of competent men in any walk of life. If this conclusion is correct, the subject I have been asked to discuss narrows itself down to a consideration of the things which distinguish achievement in industrial research from achievement elsewhere.

In any discussion of this sort we must have clearly in mind at the outset that which we wish to consider, namely, the finding and encouragement of *competent* men, that is, men competent in a creative sense or competent in those characteristics of administrative ability which make them fit leaders of industrial research groups or organizations. It is to these

men, relatively few in number, to whom we must look for those substantial results which in the last analysis will be the justification for industrial research as we have come to understand it. Without them the term "industrial research" is merely the designation of a shallow thing of little present and no prospective worth.

In both pure science and industrial research the men who succeed will be, for the most part, those men in whom the element of curiosity about nature and her ways is a controlling urge. With similar desires and similar training the forces which tend to place the individual in the pure science field or that of applied science will be those secondary influences concerned with the allurements of the academic surroundings, the desire to have one's work concretely useful, or some of the thousand factors of propinquity, heritage, environment or chance.

Per contra, I take it for granted that a man is essentially miscast and essentially a transient if he finds himself in a field of endeavor where the primary requisite for success is alien to the thing he most desires. Even if this desire is unrecognized by him at the start, it will sooner or later develop and either wean him away from his environment or leave him a dissatisfied and essentially unproductive member of a fraternity with which he is out of tune.

Put concretely, what I have in mind is that a man driven, let us say, by a zest for personal wealth and the things which personal wealth will buy, is essentially miscast if he embarks in a field which does not lead pretty directly to individual personal wealth. The occasional case, of a man capable of turning the opportunities of an otherwise unpromising occupation to the advantage of an aspiration which would normally find its easiest accomplishment elsewhere, is no refutation, I think, of this thesis. Wealth resulting directly or indirectly from one's work, on the other hand, may be and frequently is quite different from the desire to accumulate a fortune.

Or, take the case of the man whose greatest satisfaction is tied up with his desire to exercise power over his kind. He is in unhappy surroundings, momentarily at least, if perchance he finds himself engaged in an occupation the apex of whose success is power over the force of nature.

Except in a minor way, there is no large available reservoir in which we can fish for men of proven competency in industrial research. Here and there we may, if we are so minded, pick out a man who has won his spurs in the field of pure science and transfer him to our industrial research, or we may on occasion avail ourselves of an opportunity to transfer a man of maturity from one part of the industrial research world to another. Neither of these processes is, however, of any considerable value in strengthening industrial research. The first is a questionable procedure, particularly if indulged in freely, since the price paid for a temporary advantage is the almost certain degradation of the ultimate supply of trained men and new fundamental knowledge. The second is a mere shuffling of the cards in the deck and in some cases is ethically objectionable.

To those of us who are concerned with the building up and perpetuation of industrial research groups to function effectively year in and year out, the problem of finding competent men boils down in the last analysis to our ability to find competent *young*

men and, having found them, to bring them into the organization, provide them with the facilities and encouragements for growth, and ultimately to make leaders of them. For the most part our search leads always in the same direction, namely, to the parts of those institutions where men are given advanced training in science.

Out of the youthful timber which we find here we must make our selection. Occasionally the choice is easy —more often hard. To know and appraise a man well one must live and work with him for a long period. For the most part we who are in search of men do not have this opportunity. We must rely on such casual tests as our experience leads us to think worth applying. We should in the main be able to eliminate those who have inadvertently chosen an uncongenial occupation and who even though temporarily inducted into the industrial research field will not continue there for long. We should likewise be able in many cases to eliminate those who, while properly cast in the field of scientific research, would nevertheless find the environment of the industrial research laboratory distasteful as compared with the atmosphere of the college or university. Occasionally but not always we may be able to eliminate the precocious but superficially brilliant youth. It is from the remainder, after these eliminations, that we must make our choice. That choice should be entrusted to men of experience and understanding.

In my twenty-five years of association with industrial research I have had occasion personally to select many men. Looking back over an experience of successes and failures, it seems to me that in the majority of the successes final judgment was based about one-third on my personal appraisement and about two-thirds on the considered judgment of a baker's dozen or so of men in the academic world who had had a relatively long and intimate opportunity to observe the subject of choice. Per contra, in the majority of cases which were not successes I am inclined to think that too little attention was paid to the experienced judgment of those in the best position to know, or too much dependence was placed on the expressed opinion of those whose judgment I should have distrusted for any one of a number of reasons.

Summed up, therefore, I should say that in attempting to select young men who in later life will be successful in industrial research, a primary requisite is to come to know the wise men in our college, university and technical school faculties whose judgment applied to the young men they have instructed makes them a more efficient sieve than any casual outsider can hope to be. True, they may not be able to tell you that "X" or "Y" is suitable for your particular situation—that is a matter which you alone are in the best position to judge. They should, however, be able to give you substantial advice, not only as to character but as to the reasonable chance that the youthful evidences of ability are the early fruits of a substantial continuing harvest and not merely an exotic flowering or the reflections of a casual environment.

In the matter of encouragement there is, I think, but little to be said. In a general way we of industry can give encouragement which induces young men to choose aright in the selection of their college and university training. More specifically, when competent men come to us we can see

to it that their surroundings, the conditions of their association with their fellows, and the tools with which they work, are congenial and adequate. Above all, we must see to it that a just recognization of their achievements is accorded them. While adequate monetary reward in the form of salary or otherwise is a necessary and very important part of the problem of encouragement, it is in many cases, beyond a certain point, less important to peace of mind and continued productivity than are the conditions of environment and of a sympathetic human understanding of things accomplished, obstacles overcome or problems to struggle with.

Neither with respect to the matter of choice nor with the problem of encouragement are there in the field of industrial research, more than elsewhere, any hard and fast rules which can be applied with machine-like precision. We are human beings dealing with other and, to a large extent, with younger human beings. The constants and variables of our particular equations may differ but they are still the same equations with which other groups in other fields are struggling to solve like problems. Our success or failure in the selection and encouragement of men in the industrial research field is to a large extent a test of individual skill and judgment.

The Secret of Riches

"Buying good stocks for long-term appreciation is not speculation, but a very large part of all stock buying is rash, ill-informed and due solely to temporary delusions of grandeur which disappear with the next falling market.

"It is the instinctive if not consciously reasoned out appreciation of such facts as these on the part of the great bulk of our people which accounts for the enormous and rapidly increasing sums placed in trust, the continued growth of savings banks, the augmenting popularity of annuities and the seventy or eighty billions of dollars of life insurance now in force. The young man with a wife and two children to support knows that if he buys the right common stock he will be rich some day. But he may die before he has bought enough for the purpose or before he has discovered whether his selections were wise, and then his loved ones will be in want. Unless the American dollar disappears as completely as the old German mark, he knows that the insurance-company obligation will positively do what it purports to do."

—Albert W. Atwood, in "Saturday Evening Post."

Curious Patents In Mechanical Switching

By P. C. SMITH
Patent Department

THE epoch-making invention of the telephone embodied only a two-station system. As its importance became evident, inventors began to look about for means of interconnecting a large number of telephone stations through a switching center. At that time adequate switching means were unknown except those which had been developed for the allied art of telegraphy, and these were not adapted for local use but for connecting widely scattered centers of population. Only manual methods of interconnecting lines were available but inventors at once began investigations to develop mechanical means.

In 1879, about thee years after Alexander Graham Bell's invention, an application for patent was filed which covered the first attempt at the automatic switching of telephone lines. This patent, Number 222,458, and granted December 9, 1879 to Connolly, Connolly, and McTighe, disclosed a very crude and inefficient device. Although not successful, it was the beginning of a long line of research and invention.

Since then, inventor after inventor has attacked the problem until approximately 2500 patents have been issued by the United States Patent Office relating to machine-switching telephone systems and apparatus, and at the present time such patents are being issued at the rate of approximately one every three days. In addition hundreds of patents have been issued to inventors in foreign countries, notably in Germany, France and Great Britain. Many of the inventions are crude in concept, are entirely uncommercial in their adaptability to the telephone industry, and might be termed mere paper inventions. This, however, is true of all branches of the arts and sciences since many invent who have little skill in mechanics or little knowledge of the art or science into which they have delved. However, many inventions in the art of machine-switching telephony, which in themselves are impracticable and seemingly in the nature of patent monstrosities, possess the nucleus of basic principles of machine switching. Indeed the percentage of machine-switching telephone patents which might be termed curiosities is much smaller than the percentage of such patents in other arts.

One of the most unique of the early suggestions is found in the patent to Callender, Number 511,874, granted January 2, 1894. Probably every child has arranged runways and watched marbles roll to various receptacles. This childhood game has been ingeniously utilized by the inventor for establishing telephone connections. How this was accomplished is shown fragmentarily by Figure 1, from which most of the electrical circuits have been omitted for clarity and in which only two of the possible ten subscribers' lines have been shown.

Assuming that subscriber No. 1 desires to establish a connection with subscriber No. 2, he will transmit two impulses to the central office, causing the rotary magnet RM to step the switch track 1 into connection with the inclined runway R2 and also causing the energization of the switching magnet SW1. A path is now prepared for establishing the desired connection and at this point the releasing magnet Rel is energized to release two steel balls B and B′ from the storage track 2. These roll down track 2, out upon switch track 1, which is now joined to runway R2, and thence down runway R2 to the gate G2 which has been depressed through the energization of switching magnet SW1. Upon reaching gate G2, the balls roll down and come to rest upon the contacts of cross-connecting plate P2. This plate has two pairs of contact members which, bridged by the balls, establish a talking circuit between the lines of the two subscribers.

When the conversation is terminated, the calling subscriber rings off, which operates magnet A1. This action allows the balls to drop from plate P2 onto the return runway 3 which conveys them to the elevator belt 4. This raises them again to the storage track 2 to be in readiness for establishing another connection. Had subscriber No. 2 called subscriber No. 1, only one impulse would have been transmitted which would have rotated switch track 1 into line with runway R1, and magnet SW2 would have been operated instead of magnet SW1, depressing gates in all runways but R2. Thus when the balls were released, they would have rolled down runway R1, been deflected by gate G4 and come to rest upon plate P1, thereby bridging contact members to connect substation No. 2 with substation No. 1.

An interesting feature of this invention is a storage track associated with each runway R1, R2, etc., onto

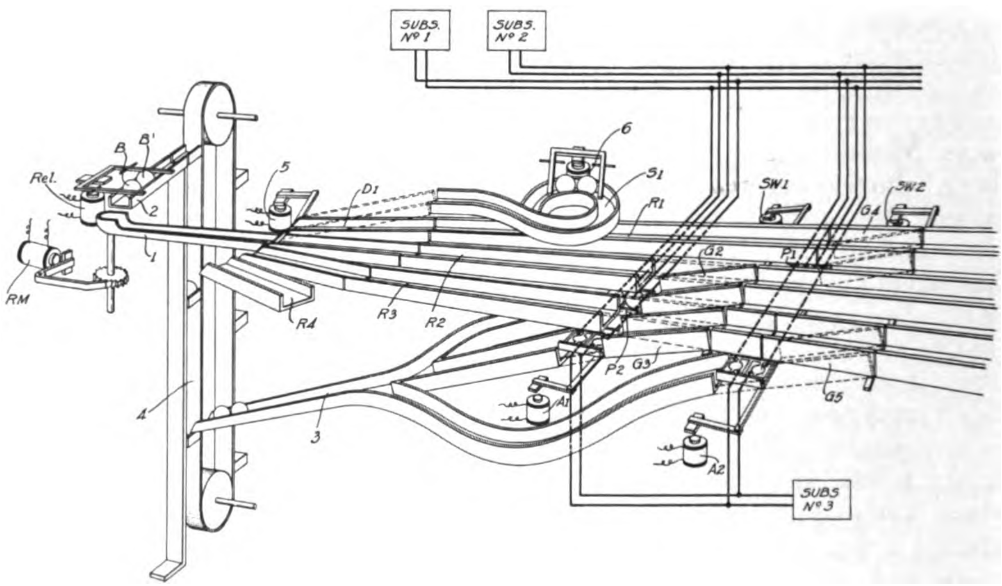


Fig. 1—An invention of Callender uses metal balls rolling down inclined troughs to make the connections between lines

which balls may be deflected. In the diagram only storage track S1, associated with runway R1, has been shown. If, for example, subscriber No. 1 has been called and another call is initiated for completion to his line, the deflecting gate D1 will be operated by magnet 5, and the balls released from storage track 2 for establishing the second call will be deflected to the track S1, where they will be held as long as subscriber No. 1 is busy. As soon as his line becomes idle, magnet 6 becomes energized and the balls are released from the track S1 and roll out upon runway R1 to complete the new connection in the manner previously described.

Another inventor has employed some of the principles of a railway system. This was Moise Freudenberg, who was granted patent Number 556,007 on March 10, 1896. The general features of his invention are illustrated diagrammatically in Figure 2. For each subscriber's line of a hundred-line system, the inventor provided an insulated track upon which was a metallic car or wagon. Just under the tracks, C1, C2, etc., and at right angles to them, was a number of metallic beams, B1,B2, etc., each connected respectively with the movable contact members D1, D2, etc., of a two-coordinate plate switch. Corresponding stationary terminals of each plate switch were multipled together and connected individually to the several subscribers lines. Each plate switch, such as P1, was provided with a car-

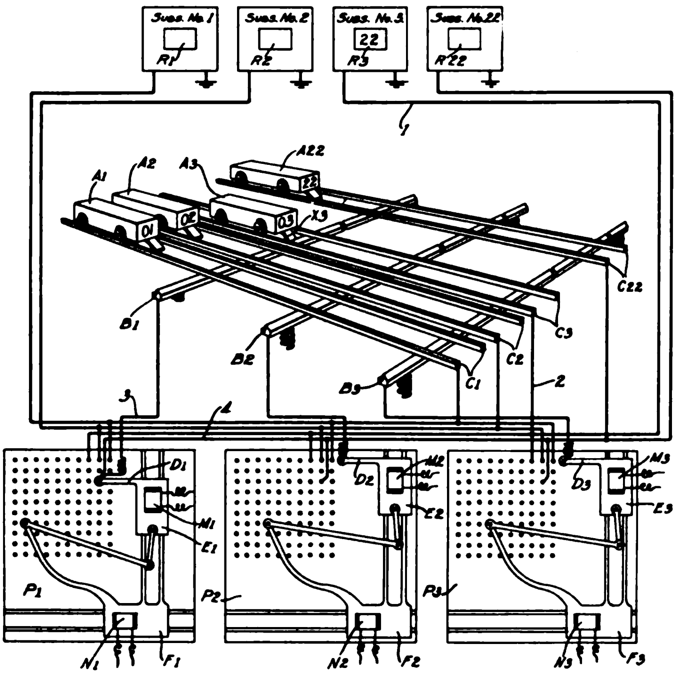


Fig. 2—A central office built in accordance with the patents of Moise Freudenberg would have resembled a large terminal freight yard. The cars supposed to make the connections between subscribers, however, would have been in size like those of toy electric trains

riage F1, moving on a stationary track on the plate and carrying a second track upon which a second carriage E1 could move at right angles to the first carriage. The contact member D1 was supported by the carriage E1. By suitable linkage and the magnets M1, N1, the two carriages were arranged to progress D1 over the entire contact field of plate P1, and the extent of the coordinate movement was recorded by a visible registering device at the calling subscriber's station.

If, for example, the subscriber No. 3 desired to establish a connection with the substation of subscriber No. 22, he started his wagon A3, by electrical means, out upon its track C3 to hunt for a beam B. A projection X3 on the under side of the wagon hit the first idle beam, made electrical connection with it, and swung it down out of reach of any other subscriber's wagon. The plate switch to which this beam was connected was now at the service of the calling subscriber. If any other subscriber desired a connection his wagon would pass over the depressed beam of the plate switch which was in use and avoid interference with the existing connection.

Immediately the connection to P1 had been established, by the projection X3 of the car A3 making contact with and depressing B1, the plate switch was set in motion by operation of magnets M1 and N1. The contact member D1 was swept over the contact field, and as it moved registered on the calling subscriber's register R3 each position assumed. When the calling subscriber saw the desired line number, 22, appear on his register, he released a button which arrested further movement of the plate switch. He was then connected with the desired subscriber's line, No. 22, over a talking circuit extending from ground, through his substation-set, wires 1 and 2, track C3, wagon A3, projection X3, beam B1, wire 3, contact member D1, terminal Number 22 of the plate switch P1, wire 4, through the subscriber's substation-set Number 22 to ground.

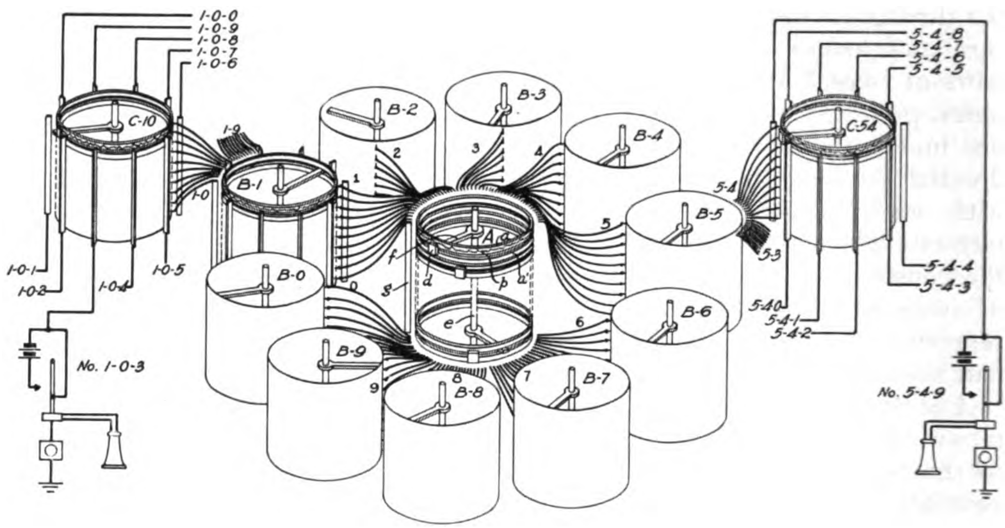


Fig. 3—A patent granted to J. W. McDonough discloses features more nearly allied to the trend taken by later development

The telephone system devised by J. W. McDonough and for which he was granted patent 538,975 dated May 7, 1895 is also quite unique as the inventor has proposed phonographic announcing means at each switching stage to inform the calling subscriber of the progress of his call. This system, illustrated diagrammatically in Figure 3, consisted of a central switch A having a number of pairs of rings, a, a^1, arranged one

above the other, one ring of each pair bearing a phonograph record p. Sliding upon the outer surfaces of each pair of rings was a contact carriage holding a magnet, certain levers, and catches, and a phonographic transmitter. Supported at the axis of the rings was a shaft e rotated continuously by an electric motor and adapted through radial arms f to push the carriages around their respective pairs of rings. Arranged around the outer periphery of the switch were one hundred vertical bars or gates g divided into ten groups of ten each, with which the carriages made contact in their movement. In general, the construction of the other groups of switches B and C was similar except that each terminating switch C had but ten gates.

The ten groups of gates of the cental switch A were connected by wires to the ten pairs of rings on the ten switches of the B group, and the ten groups of gates of each switch B were connected by wires to the ten pairs of rings on ten terminating switches Co, C1, etc. The ten gates of each switch C were in turn connected to a group of subscribers' lines. Thus a single switch A, ten switches B and one hundred switches C gave access to the lines of one thousand subscribers.

In making a call a subscriber, No. 1-0-3 for example, would take his receiver from the hook and listen to the signals 1-0-1, 1-0-2, etc., until he heard his own number 1-0-3 when he would depress a button to stop a carriage of switch C10, thereby connecting his line to switch B1. As the carriages of switch B1 rotated, signals were sent out 1-0, 1-1, 1-2, etc. Upon hearing his own division number 1-0 the subscriber would again depress his button stopping switch B1, thereby connecting his line to the central switch A. The subscriber now heard the numbers of the gates past which the carriages of switch A were passing and upon hearing the first digit 5 of the desired subscriber's number (for example, 5-4-9) he again depressed his button, giving him access to switch B5 of the fifth group. In a similar way, he heard the numbers 5-4 and 5-4-9 transmitted by the successive operation of the group switch B5 and terminating switch C54.

These early inventions although highly impracticable possessed some features which appear in all modern automatic switching systems; and the early inventors must be given credit for the contributions which they made.

A New Telephone Door for the Retail Shop

By L. J. BOWNE
Systems Development Department

SHOPPING by telephone is widely accepted as a modern convenience. Small business establishments such as grocers and butchers have employed the telephone for soliciting and accepting orders ever since it came into commercial use, obtaining by this means a considerable increase in business at the small expense of telephone service. Such service is fast, as the customers usually are well acquainted with the proprietor or clerk, who knows practically the whole stock in trade.

Large department stores have realized that the telephone could be profitably employed for shopping in their line also if the personal contact, which is automatic in the case of a small establishment, could be obtained, and if the switching required to handle telephone orders were of a simple character. By selecting a permanent group of specially trained clerks to handle all telephone orders, the personal element can be secured, and by employing the No. 2 order turret the switching operations are reduced to a minimum.

Ordinarily the PBX in large organizations is a clearing house for incoming calls, but telephone shoppers as a rule do not know which department they want to talk to, and the attention of several departments may be necessary for a single order. This requires special attention on the part of the switchboard attendant in making connection to the proper department and later in transferring the call to other departments. The load from telephone shopping may be considerably greater than that from other business, and the handling of all calls at a single switchboard often necessitates more attendants and a larger PBX than would be required if different types of calls were separated. Other objections to connecting the customer directly to the various departments are the delay caused by clerks' not answering the telephone promptly, and the impracticability of maintaining systematic supervision over the telephone sales service.

A study of the problem indicated that if the telephone shopping service could be separated from the regular service, economies in handling both would be effected. These economies have been realized by using two groups of trunks from the central office, each having a separate listing in the telephone directory; one group, used for the ordinary business of the establishment, is terminated in the regular PBX; and the other, used for telephone shopping, in No. 2 order turrets.

At the order turret, incoming traffic differs from that at an ordinary PBX because no switching is involved and the patron's first contact then is with an order clerk. On an incoming call a signal lamp with a white cap lights in the section of the turret between two order clerks. A duplicate lamp lights on the opposite side

of the turret between two other order clerks and, if more than one turret is employed, similar lamps light at the other turrets. The order clerk answers the call at any one of the positions by plugging one of two single-ended cords into a jack associated with the lighted lamp. This extinguishes all the white lamps to indicate that the call has been answered, and lights red busy lamps at each position to indicate that the line is not available for outgoing service.

Operating the talking key associated with the cord connects the order clerk's telephone to the line. Ordinarily the clerk completes the call by taking a record of the order or by furnishing the desired information to the patron. Occasionally, however, when more specific information is wanted than is available at the turret, the clerk either arranges to call the patron later or, requesting him to wait, obtains the desired information for him from another department. To do this she restores the talking key, which holds the line by a bridge in the cord circuit, and then operates the key on the other cord at her position, which connects her to the PBX operator. By this method the clerk may talk to any desired station in the establishment. If desired an arrangement may be provided by which the order clerk can connect the patron also to the PBX station, establishing a conference connection by the proper operation of the two keys at her position. This eliminates the necessity of transferring the patron at the PBX and reduces the possibility of a misunderstanding, as the order clerk remains in on the conversation until it is completed.

The lines between the order turret



Fig. 1—A view of the Number Two order turret in the John Wanamaker store, New York, during a period of light load

and the central office may also be used for outgoing service so that the clerk may solicit orders or call back patrons on deferred calls.

One of the largest installations of No. 2 order turrets is in the John Wanamaker store in New York City. Here a total of 105 central-office trunks are connected to eighteen turrets. Forty of the trunks are connected directly to the No. 2 order turret and have a separate listing in the directory, while the other sixty-five trunks are multiples of the regular PBX trunks. These two groups of trunks are divided between the eighteen turrets in such a manner that each order clerk or "Personal Service Representative" has access to a portion of each group. Much of the time twenty order clerks can take care of the installation, but at times of peak load the entire seventy-two positions may be occupied.



Fig. 2—Plugs and cords are not shown in this view of the order turret but their place beneath the keys is easily visible

The location of the jacks, lamps, keys, and cords in the middle of the turret is very convenient, since it leaves the rest of the face of the turret and the top of the table free for use of the clerks in writing up orders and in posting general information.

The equipment for the cord circuits and for ten trunks is located in one end of the order turret section, and the connecting blocks for forty multiple jacks and lamps and for the relay equipment, in the other end of the section. The normal operating load for one order clerk is between one and one half and two lines, which limits the number of relays required so that it is not necessary to mount any equipment outside the section except the dial and the jack into which the attendant plugs her telephone. These are shipped separately from the turret and are installed on the job. When more than one turret is employed, multiples of the line lamps and jacks are connected in the various turrets as required.

Provision is made so that when two groups of trunks are provided from the central office, one terminated in the PBX and the other in the order turret, the PBX trunks may be multipled at the order turret, and the order turret trunks, at the PBX. This gives maximum flexibility between the two systems, for handling misrouted calls and for night service.

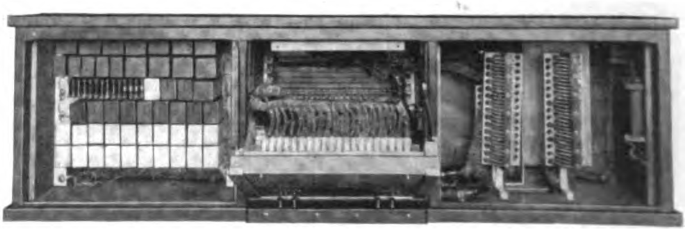


Fig. 3—With front panels removed the necessary circuit apparatus is seen in one of the side compartments and the terminal strips in the other

The same circuit arrangement is used in either case, as it is only necessary to place lamps in the lamp sockets at the positions at which the trunks are to be answered.

The No. 2 order turret is not limited to department store work since it provides means for handling large volumes of all types of inward and outward terminating traffic. Telegraph companies have been employing it for some time in receiving and delivering telegrams by telephone. Special provision is made when a subscriber has several telephones in addition to the order turret and a special PBX is not justified. Then a group of five station-line circuits, terminating in plugs, appears on one side of the central part of the turret together with the associated keys and lamps. These station lines may be connected to any trunk for either inward or outward connections, so that the turret may give service as a small PBX, but without intercommunication between these lines. They are arranged for through dialing in case the turret is in an area served by a dial office.

This order turret is found useful also for many other types of business where it is readily possible to separate the special-service traffic from that of the regular PBX or where a number of clerks are required to handle large volumes of inward and outward calls.

Saving Lead in Toll Office Cables

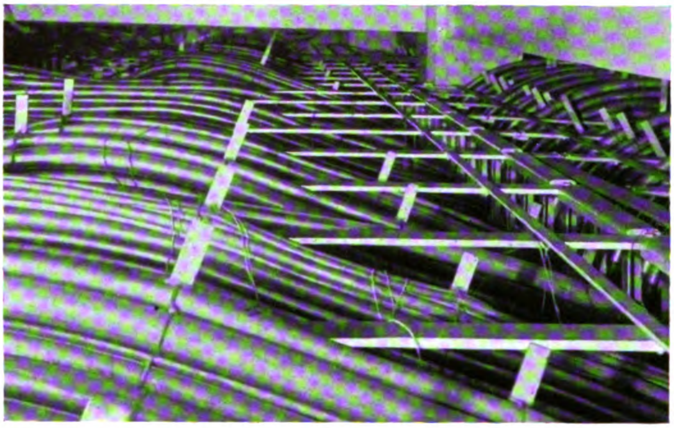
By A. KENNER
Systems Development Department

IN the early days of the telephone, wiring inside central offices was similar for toll and for local circuits. As toll lines increased in length it became more and more important to keep transmission losses at a minimum. At that time there were no telephone repeaters and therefore it was desirable for transmission reasons to use conductors as large as 16 gauge with double silk and double cotton insulation. Losses could also be reduced by increasing the insulation resistance of the central office wiring; an improvement in this regard would lessen cross-talk between circuits. Moisture is a foe to insulation resistance; to keep it from the textile coverings of the individual wires, they were enclosed in a solid lead sheath. The core was baked before the sheath was applied, and when the cable left the factory its insulation resistance was very high.

This type of cable, however, had serious disadvantages. Its weight required that the cable racks be very strongly made. To avoid kinking the cable, it must be bent to a large radius. This wasted building space by adding to the distance between frames and between the cable racks and the top of the frames. Installation was quite difficult as the stiff, heavy cables were hard to bend, strip and wax.

As lead sheathing is expensive, it was good practice to put as many wires as possible in a single sheath; this condition and others required that a large number of sizes be avail-

able in order to have a suitable one for every group of equipment. About fifty-three sizes of lead covered cables have been used for toll equipment,

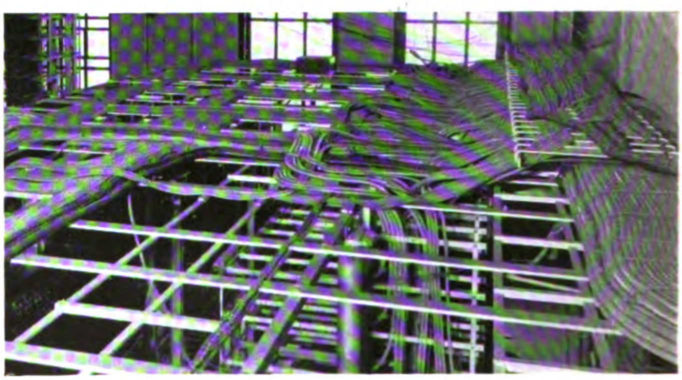


Cables passing over the tops of frames at Toledo

ranging from 10 pairs to 154 quads, part of them being 16-gauge cables and part 19-gauge cables. It can readily be seen that carrying such a large group of cables was undesirable from merchandising, engineering and installing standpoints.

In the last few years, the trend of development in equipment engineering has been toward a more compact grouping of circuit elements, so that the overall length of the main cable runs has been substantially reduced. Although lead sheath has advantages on long inside cables, it is now felt that on the short runs of the modern offices these advantages have largely disappeared. For instance, cables between the testboard and the protector frame usually do not now exceed twenty-five feet. If these are large lead-covered cables, their ends are stripped and formed out over a space four or five feet long. This meant that although lead sheath was furnished, a considerable portion of the wire was not covered by the lead when the cable was finally installed.

Cables insulated with silk and cotton and protected further by lead tape and painted cotton braid had proved satisfactory for many years in local central offices. Although the requirements in toll offices are more exacting, it seemed that under the new conditions they could be met by braid-covered cables. A trial installation was made in the new toll office at Lansing, Michigan, under the supervision of engineers from the Laboratories and the American Telephone and Telegraph Company. As a result of the trial further improvements in the



Switchboard cables at Lansing; this view shows how the smaller and more flexible cables may cross each other in several planes

insulation, the balance of the quads and the makeup of the cables have been made and special tests conducted at subsequent installations. While further improvement is being undertaken the new braid-covered cables have been made with electrical characteristics superior to those of lead-covered cables and their use in toll offices is now general.

Instead of fifty-three sizes of lead-covered cable, seven sizes of switchboard cable have been developed, which contain respectively two, four, eight, ten, twelve, sixteen and twenty quads each. It has been possible to use these cables in combination to take care of any condition. They are made up of 19-gauge wire, double-silk and double-cotton covered. Three types of quads are used, each type having a different length of twist of both pairs and quads, following the previous practice on lead-covered cables. The cables have standard pair colors which makes it easy to identify pairs and quads; the colors are arranged in consecutive pair count which is quite advantageous where the cables are used on non-quadded circuits. The cable core is wrapped with paper tape and lead tape and covered with a painted cotton braid similar to that of other switchboard cables.

Savings which follow the use of this style of cabling in future offices are not to be confined to the building space formerly occupied in cable-turning. Installation costs are less;



Lead-sheathed cables at Toledo between the toll board and the intermediate frame. This view, taken during installation, shows the heavy supporting structure

shorter cable runs are used; stocks of seven sizes of cable are more easily and economically maintained than of fifty-three sizes; and two million pounds of lead sheathing a year will be saved.

Direct Scanning in Television

By FRANK GRAY
Research Department

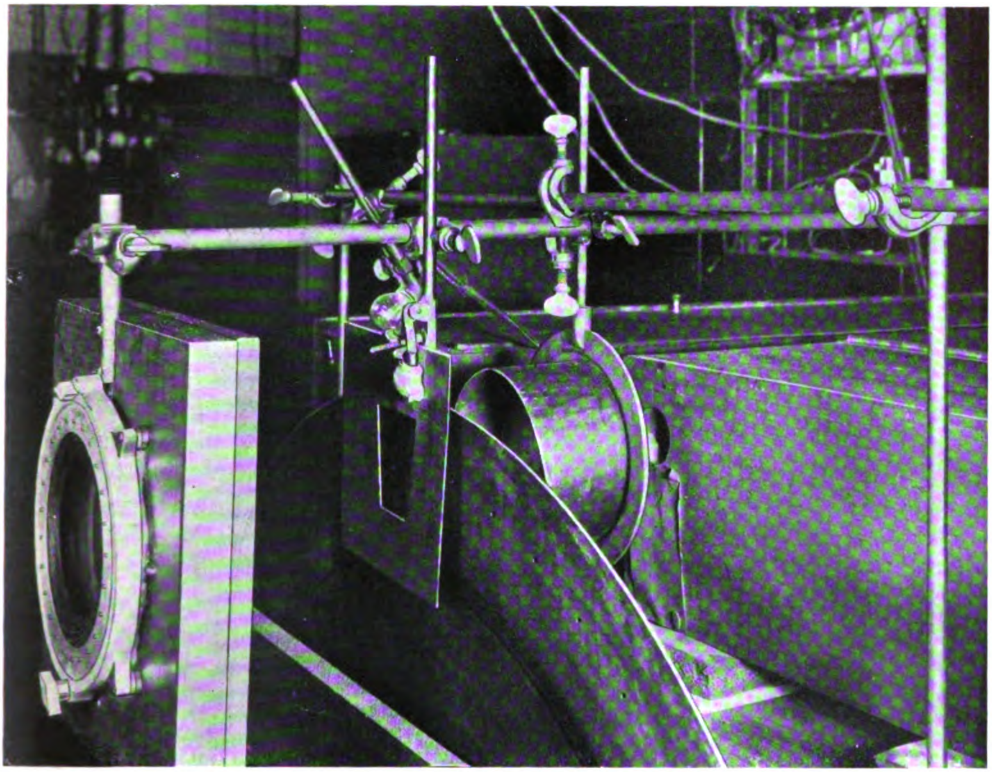
LAST July the study of certain optical conditions peculiar to television, concomitant with improvement in the sensitivity of photoelectric cells, culminated in a demonstration of the television of scenes illuminated by sunlight. In the apparatus then used the method of "direct scanning", in which an image of the object to be televised is formed by a lens on the scanning device, replaced the earlier method of "beam scanning".

The utility of any scanning method depends importantly upon the amount of light it provides to the photoelectric cell; careful scrutiny from this standpoint must precede its adoption. Beam scanning concentrates intense illumination on successive elements of an object viewed in its entirety by a photoelectric cell. In direct scanning the entire object is continuously illuminated and its successive elements are viewed by the cell. If it were possible for the two systems to be built with equal light-collecting power, it is apparent that equivalent amounts of light from any one element would reach the cells only if the wide illumination were as intense at every point as the beam at the scanned element. But the light-collecting power of any ordinary beam-scanning system is far greater than that attainable in direct scanning, for in the former several photoelectric cells with elements of large area are entirely exposed to the light. In order that two practical systems may admit equivalent amounts of light, therefore, the broad illumination must be many times greater in intensity than the beam. The expense and clumsiness of flood-lighting with the brilliance required by the early cells, and its discomfort to televised persons, dictated beam scanning for the Laboratories' earlier television systems.

Other features of beam scanning, however, are less favorable. Particularly is it unsuitable for the television of remote objects. The scanning beam can be thrown a considerable distance, but enough of the light reflected from the object reaches the cells only if they are near the object. About three feet is the maximum working distance ordinarily practicable.

Such disadvantages turned attention toward increasing the light collection of direct scanning systems and decreasing the light requirement of photoelectric cells to a feasible meeting point. With increase in the number of scanning holes used, the difficulty of accomplishing this mounts rapidly, for the amount of light required is proportional to the number of elements into which the image is divided—to the square of the number of holes. When, as last July, fifty holes are used, the problem is by no means simple.

There are properties peculiar to the optical system of lens and scanning disc which make possible an in-



Optical system for direct scanning, used for outdoor television

crease in its light-gathering power by increasing all its physical dimensions. These properties inhere fundamentally in the division of the scanned image, by the holes in the scanning disc, into a finite number of elements for transmission.

The amount of light admitted by a scanning hole to a photoelectric cell is proportional to the area of the hole times the illumination over it. Increasing the area of the hole is obviously impossible without increasing the area of the scanning disc, and fruitless without increasing the area of the scanned image. The latter can be done by using a lens of greater focal length and placing the lens at the new focal distance from the disc. If the area of the new lens is the same as before, it spreads the same amount of light as before over the now larger area of the image. To avoid offsetting, by the decrease in illumination over it, the effects of increasing the scanning-hole area, the new lens also must be of greater area. Thus, to improve the system's light-gathering power proportionately to an increase in the area of the scanning holes, every dimension of the scanning apparatus is augmented.

The effectiveness of the enlarged system can be further magnified by a still greater increase in the area of the lens, and a consequently ampler collection of light. For "illumination", in the formula for light-gathering, there can accordingly be substituted the ratio of the diameter of the lens to its focal length—the "aperture". In short, the light given the cell by the

system is proportional to the product of the hole-area and the lens aperture; improvements in light-collection can be had by increasing either or both.

For each factor practical considerations limit increase. Photographic lenses of aperture greater than that equivalent to an F-number* of 2 fail to provide adequate definition over the size of field ordinarily televised, and discs larger than ten feet in diameter are unhandy to house and liable to centrifugal breakage. But these limits need not ordinarily be approached. Operating in ordinary sunlight, and aided by the new photoelectric cell, a lens of F-number 2.5 and a three-foot disc suffice.

Complicating the application of the simple expression for light-gathering is the fact that the area of adequate definition of an image formed by a lens varies approximately with the reciprocal of the lens aperture. In any attempt to refine the grain of the reproduced picture by increasing the number of elements into which the image is divided, this new consideration adds optical difficulties to the already aggravated transmission problems. Using more numerous holes of the same size as before requires a larger disc and a larger image. Providing this image with the same illumination requires a lens with the same aperture and with larger diameter and focal length. But if this aperture was just sufficient in definition for the previous grain, it will be inadequate for the finer. To suit the lens in this respect, a smaller aperture must be used, and thus the whole apparatus must be further increased in size to retain its light-gathering power. In this way, doubling the number of picture elements would require very nearly trebling the diameter of the disc.

A fortunate feature of psychological optics makes it unnecessary to refine the grain of a picture of a full-length figure or a group beyond what is required for a close-up picture of a face. The same number of elements will serve for both, if both are of the same size. As in ordinary vision, the observer expects less detail in a distant than in a nearby scene. The criterion of resolving power is independent of the kind of objects seen; it depends exclusively on the extent of division of the field.

Direct scanning and beam scanning appear at present, therefore, to be mutually supplementary rather than competitive systems. Constructed with regard to the principles discussed, a direct-scanning system is eminently suited to the television of relatively distant outdoor scenes broadly illuminated by good sunlight. Indoors, however, where artificial broad illumination equivalent to sunlight is uncomfortable and difficult to secure, beam scanning still remains superior.

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* *The F-number of a lens is the ratio of its focal length to its diameter.*

To

Frank Baldwin Jewett

WAS PRESENTED THE
EDISON MEDAL
AT THE MIDWINTER CONVENTION OF THE
AMERICAN INSTITUTE OF ELECTRICAL
ENGINEERS



Program of the Meeting

PRESIDING: H. A. KIDDER
Vice-President of the Institute

ORIGIN OF THE EDISON MEDAL: JOHN W. LIEB
Edison Medallist and Past President of the Institute

ADDRESS: JOHN J. CARTY
Edison Medallist and Past President of the Institute

PRESENTATION: OLIN J. FERGUSON
Senior Vice-President of the Institute

RESPONSE: DR. JEWETT



Frank Baldwin Jewett

THE history of the development of telephony is one of cooperative effort with scarcely a parallel in the domain of applied science. In no other field of modern industry has the fruitage of pure science through cooperative effort been greater. Nowhere else is the industrial research organization more potent, more firmly incorporated into the business structure or more relied upon as a weapon for attack on problems yet unsolved.

Such a development in relatively so short a space of time is of course far beyond the capacity of any man or any small group of men to achieve. It is an evolutionary thing compounded of foresight, leadership and the consistent cooperation of many men through many years.

As one who has been a part of the unfolding pageant of telephony for the past twenty-five years, I am not unmindful of the influence others have had in whatever I have accomplished. In accepting this Medal, the highest and most cherished honor which American electrical engineers have it in their power to bestow, I do so therefore with a deep feeling that in large measure I am accepting your appreciation for the work of all the numerous men who have been my intimate associates. On their behalf, as well as my own, I thank you for so signal a recognition of our endeavors.—*From Dr. Jewett's Response.*

A Medal, A Man and An Idea

THIS week's action of the American Institute of Electrical Engineers in bestowing the high scientific honor of its Edison Medal on our fellow New Yorker, Dr. Frank Baldwin Jewett, redresses in some degree a balance of the personal credit which has never been quite true. Outstanding personages sometimes come to be symbols, historians observe, for their organizations; Napoleon is remembered, his generals are forgotten. Dr. Jewett's history has been precisely the reverse. In scientific circles he and his work have long been known, admired and honored—the last chiefly by that sincerest of all honors, selection to do jobs personally profitless but which need doing in the public interest. For the New York public, however, Dr. Jewett's personality has been shadowed, doubtless entirely to his satisfaction, by the growing reputation of an institution largely his creation, Bell Telephone Laboratories.

Dr. Jewett's chief contributions to science have been an idea and the skill to make that idea work. The idea is that of co-operative research. No one scientific man can know everything or possess all kinds of skill. Hence Dr. Jewett's idea of assembling groups of experts to work on complex scientific needs. Able scientists are not often well broken to harness. Teams of them are none too easy to drive or even to lead. Yet Dr. Jewett has managed this well, perhaps better than anyone else; as the success of the telephone laboratories testifies.

The idea, admittedly, is still on trial. It is too new to be anything else. That co-operative research will banish the individual inventor from technology is unlikely, especially if that inventor happens to be a genius. A century or two from now Dr. Jewett's idea is likely to disclose itself more as an entirely new tool for civilization's work-bench than as a substitute for anything else. Meanwhile, one answer to the charge that organization necessarily stifles initiative is the record of the co-operative groups whom Dr. Jewett directs in making two recent discoveries of the very highest originality; the magnetic metal called permalloy and proof of the wave nature of electrons, the latter beyond much doubt the foremost scientific event of the last five years.

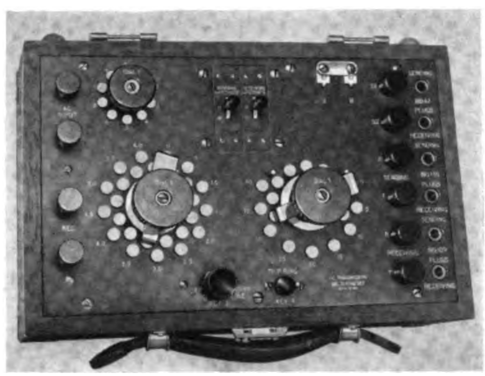
—*Editorial in New York Herald-Tribune, February* 2, 1929.

Transmission Testing of Central-Office Circuits

By H. T. DOUGLASS
Systems Development Department

IN traversing the succession of circuits linking transmitter to receiver, the voice-frequency currents involved in a telephone conversation suffer attenuation along the way. This loss of energy must be kept within close limits to insure production of an adequate volume of sound.* Accordingly the wire used in inter-office trunks and in lines running to subscribers' telephones is sufficiently large to insure transmission of these currents without excessive loss. The currents must also be protected at the central offices, in the cord circuits and in other circuits through which they pass. Loss of energy in the wiring of these central-office circuits is ordinarily a minor factor since the length of the wire is relatively small, but loss in the relays and other pieces of circuit apparatus must be considered. The impedance of apparatus connected in series with the transmission path is, therefore, kept as low, and that of apparatus bridged across the path as high, as is economically possible commensurate with the requirements for signalling, supervision and other circuit functions.

Precautions have long been taken to protect the transmission characteristic of the central-office circuits. Apparatus to be bridged across a talking circuit is tested during manufacture to insure that the inductance is sufficiently high. Inductively wound apparatus to be connected in series with the transmission path is usually shunted by a non-inductive resistance or a condenser to provide a low-impedance path for the voice currents. In the design of any circuit the loss which will be caused by the proposed apparatus combination is measured or computed, and if found to be disproportionately high the circuit must be redesigned to bring the loss within suitable limits. Circuits are given an operating test after installation, but this test although revealing defects in operating characteristics does not necessarily reveal those which might result in excessive attenuation of the voice currents.

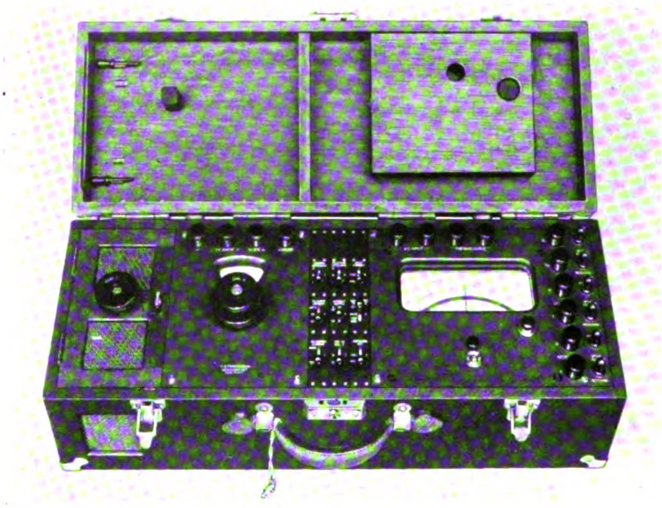


1-C measuring set, of acoustic balance type

Early in 1926 a new safeguard was introduced, that of making transmission acceptance tests of central-office circuits immediately after installation. These tests derive their

**For an explanation of the unit of attentuation see "TU Becomes Decibel" by R. V. L. Hartley in the* RECORD *for December, 1928—p. 137.*

name from the fact that a new installation is not formally delivered to the Telephone Company by Western Electric until the overall transmission losses of all the circuits over which the voice currents must pass come within specified limits. In preparation for the new practice, each central-office circuit having as its function the transmission of voice-frequency currents was analyzed and the permissible loss was decided upon. Transmission loss limits for the circuits, together with simplified sketches of the transmission paths and of the apparatus involved, are provided in a "Transmission Requirement Specification" sent out to Western Electric field forces. In the program undertaken, each circuit drawing will eventually furnish information by means of which the maximum allowable transmission losses for the circuit can be determined.



A meter-indicating set, type 3-B

Field acceptance tests are made by means of a transmission measuring set. Testing current is supplied by a 1000-cycle oscillator, and an "adaptter" unit is used to hold the circuit under test in its talking position while the measurements are being made. Two types of transmission measuring sets are in general use at present, one indicating the measurements through a balance of tones and the other by a galvanometer. In the use of each, 1000-cycle current is impressed on the central-office circuit to be tested and on a variable network whose attenuation is known at all times. The network is adjusted until the current passing through it is attenuated to a known extent and is equal to the current reaching the far end of the circuit; the transmission loss is then read on the dials of the network.

A set giving measurement by acoustic balance, shown schematically in Figure 1, is used on smaller installations and also at all magneto switchboards. A definite alternating potential is impressed on the input side of the circuit under test, and on the vari-

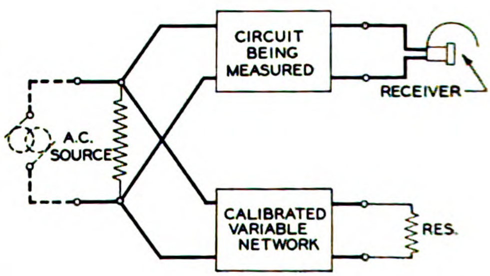


Fig. 1—Acoustic balance type of transmission measuring circuit

able network of the measuring set. For observing the state of balance, a telephone receiver is connected to a key in the measuring set whereby it may be connected alternately to the two branches. That the output load may be kept constant, a resistance equivalent to the receiver impedance is connected to each branch in turn, while tone from the other is observed. To make the measurement, dials of the variable network are adjusted until the volume of tone produced by the receiver is the same when coming from the circuit under test as when from the network. Then the loss in the circuit under measurement is equal to that of the variable network, and is indicated directly in decibels on the dials of the measuring set. Transmission losses from 0 to 46 decibels may be measured by sets of this type with an accuracy of ± 0.5 decibels.

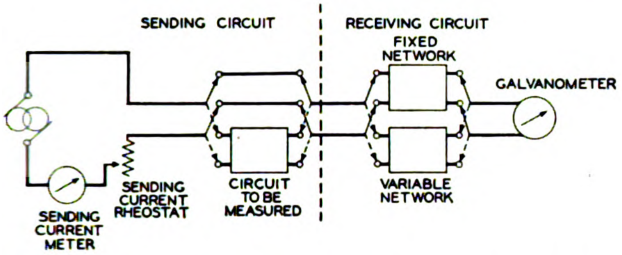
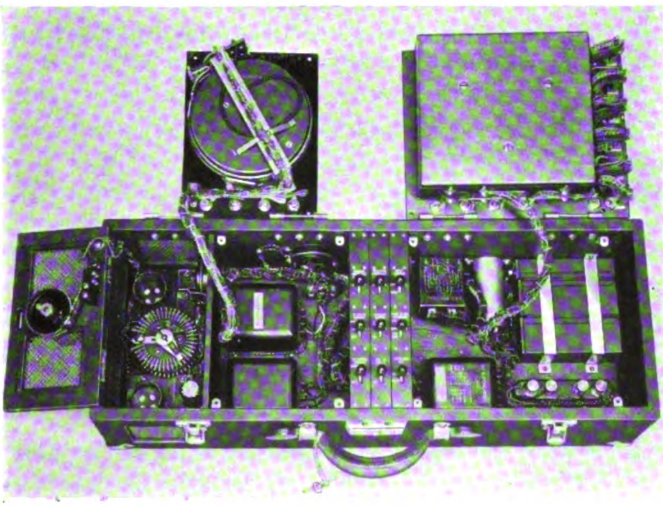


Fig. 2—Meter-indicating type of transmission measuring circuit

To afford more accurate measurements and to eliminate the uncertainties brought by the human element involved in comparisons of sound intensities, the meter-indicating type of measuring set is used on all larger installations in common-battery offices. This set is capable of measuring transmission losses of 0 to 40 decibels, with an accuracy of ± 0.1 decibel. The operations involved in its use are considered as divided into calibration and measurement.

The first of these operations, as the name suggests, determines a galvanometer reading which will later serve as a criterion of balance. Alternating current is supplied to the set by a 1000-cycle oscillator, and the energy input is held constant by an adjustable rheostat. Part of the energy flows through a fixed network whose transmission loss is known, and the resultant current at the output end is given by the galvanometer. In the second group of operations the circuit to be tested, connected in series with the variable network of the set, is substituted for the fixed network. Then the variable network is adjusted until the



Interior of 3-B measuring set

galvanometer reading is the same as during calibration, and the transmission loss of the circuit under test is read directly from the graduated dial whereby the network was adjusted.

Transmission acceptance tests are made by a special team of installers between completion of the operation tests and the time the apparatus is turned over to the Telephone Company. In all cases as much as possible of the circuit wiring is included. A test of an interoffice trunk, for instance, takes in not only all the relays and other pieces of apparatus, but as much of the wiring as can be included; wires from the measuring set are connected to the circuit at the main distributing frame, and the plug of the trunk cord is inserted directly into a jack of the set. An allowance is made for the loss in the wiring between frame and measuring set.

When the loss caused by the circuit is found to be within the specified limit, the circuit is considered satisfactory for delivery to the Telephone Company. If, however, the loss is found to be excessive and a check does not disclose, for instance, incorrect or faulty wiring or defective contacts, each individual piece of apparatus is measured to locate the fault. The non-inductive shunt across a relay winding may be open, there may be short-circuited turns in a piece of inductive apparatus bridged across the circuit, or low capacity may be found in a condenser in series with the line.

During the first nine months in which telephone circuits came under this new form of scrutiny, troubles which had not been picked up in the regular operating tests were found on one per cent of the circuits tested. Certain of these defects would probably have been located by a testman later. Others, not affecting the operating characteristics of circuits, might have continued. Although the losses introduced by these might be negligible for any individual circuit, their effect would be cumulative and under certain conditions of connecting circuits together, the transmission might be appreciably impaired.

The new testing program, assuring standard transmission on all circuits from the outset, is a logical complement to the operating tests and another evidence of the determination to take every step economically possible toward better telephone service.

Small Power Plants for Telephone Repeaters

By J. L. LAREW
Systems Development Department

FOR the plate and filament circuits of vacuum tubes there must be local sources of direct current at suitable voltage and free from noise-producing components. Power plants for supplying extensive vacuum-tube loads have been in existence at the larger offices for years; they use the existing 24-volt battery for filaments and a 130-volt storage battery for plate circuits. With the introduction of the type D-1 carrier system, however, provision for a suitable power supply became imperative in offices of the magneto type where no office battery is used. Likewise in small common-battery offices, where a few two-wire telephone repeaters or D-1 carrier equipments might be applied, a source of plate supply would not be available, since the battery of the local office would not have a potential as high as necessary. The current-drain requirements for filament and plate supply, however, are exceptionally small in such installations.

In the past, motor-generators charging open-type storage cells have often been installed for small loads. Acid fumes liberated by the open-type cell during its charging period were confined either to a room in which the equipment had been especially protected against corrosion, or to a battery cabinet properly ventilated to the outside atmosphere. Recent progress, however, has provided means for avoiding the use of motor-generators and open-type storage cells. Suitable rectifying devices and enclosed-type storage cells have been designed and, due to the large demand, produced at exceptionally low prices. This made it advisable to use the Tungar type of rectifier and the enclosed glass-jar storage cell in small power plants.

Being relatively small, the cells are grouped in units which are convenient for handling. Each cell is equipped with a vent cap which prevents the liberation of electrolyte during charge. Such features have made it possible to mount the cells on a standard relay-rack framework without requiring that the iron work be protected against acid corrosion. Considerable economies in power-plant design have, therefore, been effected, as isolation of the batteries from the charging equipment is no longer required. This makes it possible to arrange a complete power-plant unit on a standard seven-foot relay rack, which may be located at the most convenient point in the office with respect to the load, and thereby insures an economical arrangement of the wiring between the power plant and the load. Additional economies in the wiring have been effected by locating the distributing fuse and lamp panels on the power bays.

There was an urgent, immediate need for such small power plants. To avoid the delay incident to the development and test of automatic-control apparatus, it was decided to

produce plants controlled by hand. One of these delivers two amperes at twenty-four volts for filament circuits and the other, 130 milliamperes at 130 volts for plate circuits. As these are designed for exceptionally small currents, the number of circuits supplied by each is relatively small, so that fuse and lamp mountings may be grouped with the power plants. This

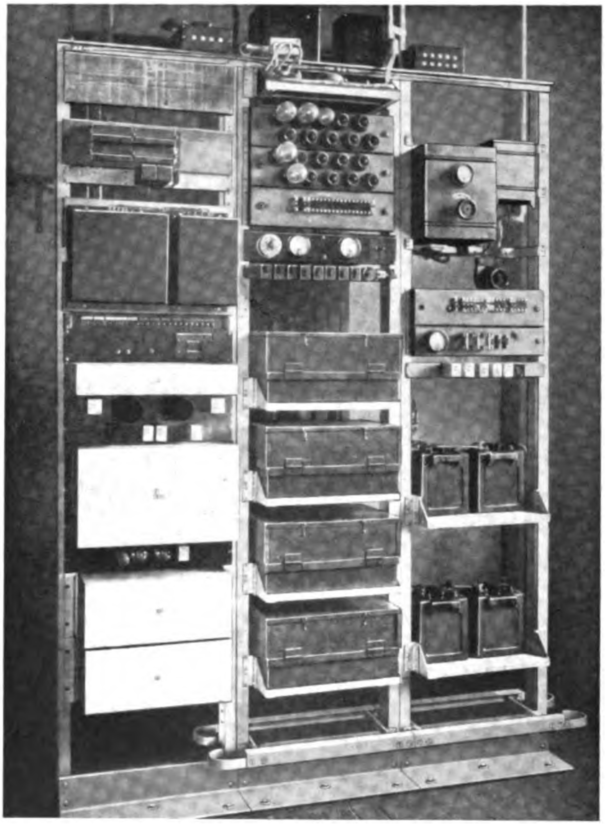


Fig. 1—A type D-1 carrier terminal (left) and its power supply: center, the 130-volt plate batteries, charged by the rectifiers on the top of the panel; right, the 24-volt filament batteries, charged by their own rectifier

is more economical than having a fuse board separate from both the power plant and the load, which is the method universally used when a large number of fuses are required. By mounting the equipment to be supplied on adjacent relay-rack bays, cabling between the two becomes a simple matter, avoiding the necessity of cable racks and longer cabling between the power plants, fuses, and load.

The 2-ampere 24-volt power plant employs a single 11-cell battery, floated by means of a Tungar rectifier, and is mounted on one bay of standard nineteen-inch relay rack. The batteries are set on shelves in the lower portion of the rack, while the rectifier with its associated control equipment, distributing fuses, and alarm annunciator equipment is located above. The load on the plant, being vacuum-tube filaments, is so nearly constant that after setting the rectifier to deliver a suitable value of current, the battery will be maintained at a state-of-charge well within its working limits without further attention. Therefore the additional expense of voltage-control equipment is not justified for this plant.

The 130-milliampere, 130-volt plant also requires one bay of standard floor-supported relay rack. It employs two 66-cell batteries; a high-voltage Tungar rectifier is the charging source. One battery is charged while the other is being discharged by carrying the load. The transfer of the batteries from charge to discharge or vice versa is made manually and, because of the manual control, these power plants cannot be left unattended for any great length of time.

The small glass-jar type of storage cell used in this plant is equipped with charge-indicator balls. Usually three such balls, free to move in the electrolyte, are provided in the pilot



Fig. 2—Two racks are required for the larger battery of the 800-milliampere power plant, which is also automatically operated

cell. The most common colors are green, white, and red. The balls are not attacked by the electrolyte, and the specific gravity of each is so selected that a different colored ball will rise or sink as the specific gravity of the electrolyte changes due to a charge or discharge of the cell. All three balls will be at the top of their path when the cell is fully charged and at the bottom when completely discharged. Such an arrangement obviates the necessity of frequently using the common syringe hydrometer. On the front and rear sides of the battery are inspection doors to permit examining the charge-indicator balls and electrolyte level without removing the box covers.

The immediate demand for power plants of this sort being satisfied, development work was started to devise means for controlling small plate-power plants automatically, in order to reduce the attendance and



Fig. 3—The 200-milliampere, 130-volt plant. At the top is the Tungar rectifier; next come the resistance lamps and fuses. The relays are for automatic charging and voltage control. In the four lower boxes are the storage cells

maintenance incident to manual operation. As a result the 800- and 200-milliampere 130-volt power plants, shown in Figures 2 and 3, have been completed. These are arranged to control their output voltage between the limits of 125 and 135 volts automatically. Two batteries in parallel are continuously floated across one or two Tungar rectifiers. A coil connected between the ungrounded ends of the two batteries forms the reactance element of a simple filter, of which the batteries form the resistance elements. This filter effectively prevents alternating currents from reaching the load circuits. Two bays of floor-supported relay rack are required for the 800-milliampere 130-volt power plant, while only one is required for the 200-milliampere plant, because of the difference in space required by their batteries.

As is the case in the smaller 130-volt power plant, the batteries are housed in boxes, and have the necessary charging, control and other equipment mounted on the upper portion of the power-plant unit. Since these plate power plants are arranged for automatically controlling the output voltage and properly floating the batteries, their introduction can be considered as a step towards the realization of future unattended power plants.

New Space for the Laboratories

The Laboratories has acquired approximately 40,000 *square feet of additional floor space in the new twelve-story "Maltz Building" on the southwest corner of Hudson and Canal Streets, New York City, facing the plaza associated with the Holland Vehicular Tunnel. This space, the entire* 10*th and* 11*th floors of the premises, has been leased for five years beginning May* 1, 1929. *The* 10*th floor will be occupied by the Outside Plant Development Department, which now occupies the 2nd and 3rd floors of Sections J and K. The space vacated by that department will be utilized by the Systems Development Department for additional laboratory facilities. The* 11*th floor will be occupied by members of the group working under the direction of O. E. Buckley, and by other groups in the Research Department. Plant adaptations have already been begun, and the space will probably be completely occupied early in May.*

Level-Hunting Connectors

By F. A. KORN
Systems Development Department

IN the step-by-step dial telephone system, connectors are the switching mechanisms that make the final connection to the line called. To connect a private branch exchange, with more than one line from the central office, a "hunting" connector, rather than the regular non-hunting one, is required so that a selection may be made of the first line in the group that is not in use. Hunting connectors used heretofore have, in general, been able to select from only ten lines. When more than this number are required, the lines are divided into sub-groups of not more than ten each, each sub-group reached by only part of the connectors. The disadvantages of this method are comparatively unimportant when the size of the group is not greatly in excess of ten, and the method will continue in use for certain cases. For large PBX line groups, however, an arrangement becomes desirable for hunting over all the lines in the group with a single switch. The recent development of the level-hunting connector, which can hunt over as many as one hundred lines, provides such an arrangement.

An ordinary connector has access to one hundred lines, the terminals of which are grouped in ten layers or levels, each having ten lines arranged around a section of circular arc. Such a group of one hundred pairs of terminals is known as a "bank." Every subscriber's line has, in addition to the two employed for talking, a third wire known as the "sleeve" lead, which is used for control purposes. These leads are also wired to a bank called a "sleeve" bank mounted just above the line bank. A vertical rod, on which are arranged copper brushes or "wipers" for making connections to these terminals, is mounted in front of the banks of terminals. This rod with its associated wipers may be moved by means of suitable ratchet and pawl arrangements, first vertically to any desired level and then horizontally to any terminal in that level. The upward motion of the rod is from one level to the next above and the horizontal motion, from one terminal to the adjacent one, for each operation of the "vertical" or "rotary" magnet. The wipers thus move up and around step-by-step in a fashion typical of this system of dial operation.

In engineering step-by-step central offices, lines to private branch exchanges, commonly termed "PBX trunks", are segregated into certain hundreds groups which terminate on hunting connectors. This practice is followed because the more expensive hunting connectors are required only for the PBX trunks while regular connectors will serve for individual lines. These latter lines, however, may be assigned to trunks in the PBX hundreds groups. Trunks to private

branch exchanges are assigned numbers in a definite sequence and the number of only the first trunk appears in the directory. A PBX subscriber, for example, may require eight trunks

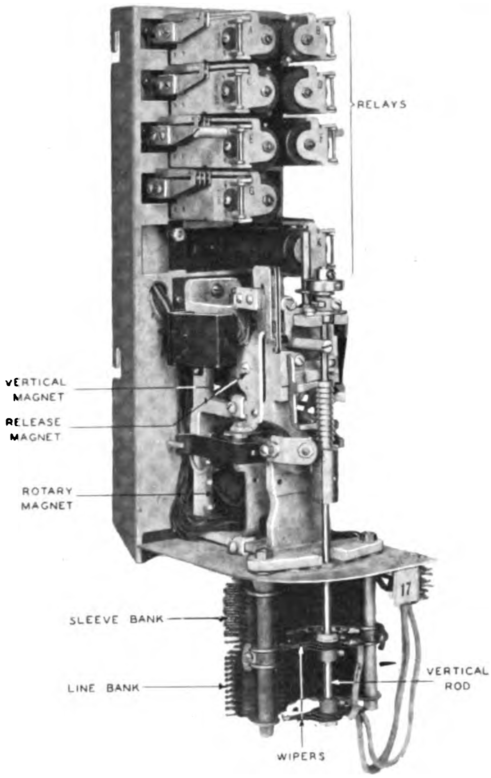


Fig. 1—On this photograph of a regular connector are indicated the essential operating elements

to a central office, numbered consecutively from 1032 to 1039. The telephone directory, however, lists only 1032.

In manual telephone practice the multiple jacks of these trunks are indicated by a distinctive painted marking so as to be recognized by the operator. When a call is received for the first trunk of such a PBX group the operator tests the jack associated with that trunk and, if it is busy, will test jacks associated with other trunks of the group consecutively until an idle one is found. If all trunks of the group are busy the calling subscriber will receive the busy signal.

In a dial telephone system means must likewise be provided for completing calls to a private branch exchange by any of its associated central-office trunks even though the first trunk only is listed in the directory. Furthermore, the equipment in a dial system must recognize the trunks of a PBX group so that if the first trunk dialed tests busy, other trunks to the PBX will be tested until an idle one is found. The switching equipment must be arranged also to stop testing at the last trunk of the group and to give a line-busy indication to the calling subscriber if all trunks are busy. These requirements must be met for any type of hunting connector.

The level-hunting connector differs from the rotary hunting connector in being able to hunt over all ten levels, if necessary, instead of a single one. To accomplish this two additional pieces of equipment are required. One is a commutator and vertical wiper, evident in the accompanying photograph. The vertical wiper is fastened to the rod controlling the wipers used with the bank terminals. The commutator contains eleven segments, ten corresponding to the individual levels of the connector banks and one used as a resting place for the vertical wiper when the shaft is normal. It is attached to the lower cover plate of the switch and its terminals are wired to the terminals of one arc of the ten-point "register" switch, the other additional piece of equipment. This register switch, with two arcs each of ten terminals, over which wipers rotate, is used to direct the connector to the proper level and to

control the release of the switch during the level-hunting process. It is designed to mount horizontally below the relay equipment on the switch mounting plate.

Assume, for example, that a subscriber, with a listed number of 1231, had an assignment of forty-five trunks. This listed number would correspond to the lowest connector terminal and the assigned trunks would use the entire third, fourth, fifth, and sixth levels of the connectors of the group. The other five assigned trunks would be associated with the first five terminals of the seventh level, but the remaining terminals of this level would be retained for growth and not assigned to other subscribers. The dialing of digits "1" and "2" by a calling subscriber will cause the step-by-step equipment to select an idle trunk to a level-hunting connector which has access to the PBX group desired. In the operation of the level-hunting connector, only the tens digit of the listed directory number—the number "3" in this case—is effective. The units digit, however, is retained for uniformity of numbering and records.

When the dial restores to normal on the completion of dialing the digit "3", the register switch responds by taking three steps and stopping on the third terminal. Through electrical connections between the register switch and the commutator, a distinctive indication, consisting of a ground, is placed on the commutator segment to determine over which level the switch shall first hunt for an idle trunk. This cross-connection scheme provides means for employing different level-hunting switches to hunt over various connector bank levels in any desired and predetermined order, thereby reducing the average hunting time and switch wear. If these cross connections are in regular order, the third terminal of one arc of the register switch being connected to the third commutator segment, the fourth terminal to the fourth commutator segment, and so on, the connector will, at the completion of the dialing of the digit "3", step first vertically

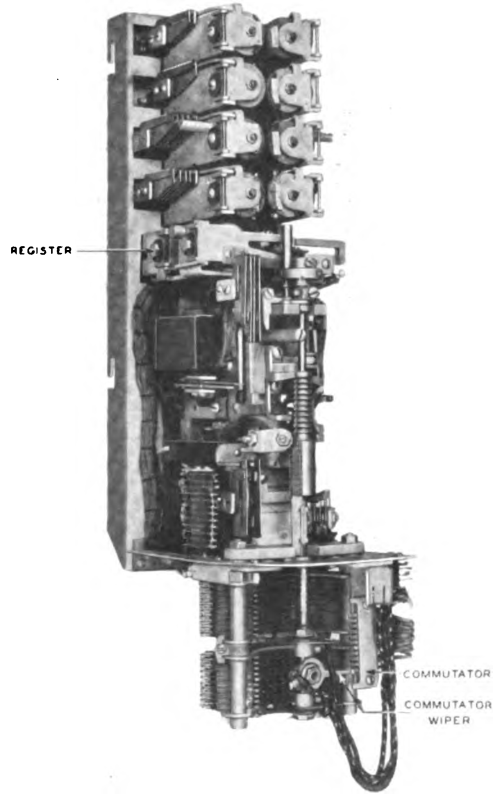


Fig. 2—A level-hunting connector differs from an ordinary connector principally by the addition of a commutator and a register switch

to the third level and then rotate horizontally to seize the first idle trunk.

When all trunks of the group are idle the switch will stop and connect to the first trunk of the group; that is, line 1231. If a second subscriber

now calls the same PBX he will not receive the busy tone but will be connected through on the second trunk, line 1232. A third calling subscriber will

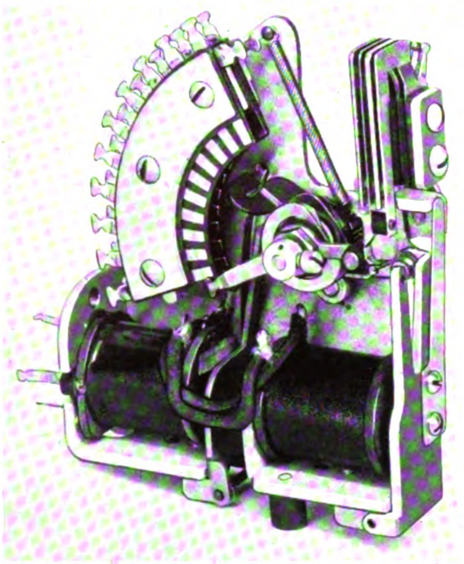


Fig. 3—The structure of the register switch, not clearly discernible in Figure 2, is evident here

be connected to the next line and so on till all trunks on the level are busy.

When this occurs and another subscriber dials 1231, the connector, after testing the trunks of the third level and finding them busy, will automatically release and at the same time the register switch will advance to the fourth terminal. This causes the distinctive marking indication to be transferred from the third to the fourth of the commutator segments so that after the shaft has dropped to the normal position the connector will automatically step to the fourth level and rotate to test the trunks there. If a trunk appearing on this level is idle it will be seized and the connection established, but should all trunks on this level also be busy the connector will again automatically release. With the restoration of the shaft to the normal position the register switch will be advanced to the fifth terminal and the distinctive indication transferred from the fourth to the fifth segment of the commutator. This action will continue until an idle trunk is found or until all trunks of the group have been tested. If all trunks of the group are busy, a distinctive tone called a "line busy tone" will be given the calling subscriber and the connector switch will not automatically release after the last trunk of the last level is tested.

Report on Employees' Benefit Plan

In a statement directed "To All Active and Retired Employees" under date of February 8, 1929, the Employees' Benefit Committee calls attention to certain changes made during the past summer in the Employees' Benefit Fund Plan for the purpose of improving the pension and other benefit provisions of the Plan. The statement, which is signed by H. D. Arnold as Chairman of the Employees' Benefit Committee and approved by President F. B. Jewett, is as follows:

"The Report on Employees' Benefit Fund as published in the BELL LABORATORIES RECORD, March, 1928, called attention to a change, effective as of January 1, 1927, in the 'Plan for Employees' Pensions, Disability Benefits and Death Benefits,' adopting a systematic method of providing funds for the payment of service pensions and, to some extent, broadening the obligations of the Laboratories with respect to such pensions.

"As a further step in improving the pension and other benefit provisions of the Plan, the Committee, with the approval of the President and the Board of Directors, has made additional changes therein effective July 1, 1928. These changes have all been embodied in a revised Plan, copies of which may be obtained from the Employee Service Department.

"The principal changes in the Plan from the provisions in effect prior to 1927 are:

(a) The obligations of the Laboratories with respect to payments under the Plan, as it may be in effect from time to time, have been extended so that they are no longer limited by the conditions stated in what were formerly Sections 11 and 12 of the Plan.

(b) All payments under the Plan other than for service pensions are charged directly to the operating expense account of the Laboratories and not accounted for through an 'Employees' Benefit Fund' as heretofore. (These payments represent current expenditures, covering for the most part short periods only and tending, from year to year, to bear a fairly constant relationship to the total payroll of the Laboratories.)

(c) All service pensions (that is, pensions granted under the provisions of subsections [a] and [b] of Paragraph 1 of Section 4 of the Plan) are provided for by a Pension Fund. This Pension Fund is sufficient in amount to meet all existing liability in respect of service pensions of retired employees as well as employees eligible to retire at their own request. It is held by a Trustee and is now invested in interest-bearing securities of the Laboratories, and can be used only for service pension purposes as directed by the Laboratories from time to time. The Laboratories has undertaken to maintain this Fund by periodic payments thereto in such amount that, when employees become eligible under the Plan to receive pensions at their own request, there will be available in this Pension Fund an amount

which will be sufficient to provide life pensions of the amount stated in the Plan.

(d) The 'Employees' Benefit Fund' and the related Employees' Benefit Reserve accounts are no longer maintained, assets represented thereby having been transferred as of June 30, 1928, to the Pension Fund—the trust fund established under the Plan to meet service pension requirements. The establishing of this Pension Fund eliminates the necessity of these accounts on the books of the Laboratories.

"It will be noted that these modifications relate to the safeguarding of the pension features of the Plan and to the method of providing funds to meet future requirements and of accounting for payments under the Plan. They do not in any way affect the right of the Laboratories to make changes in the Plan, provided such changes do not affect the rights of any employee to any benefit or pension to which he may have previously become entitled under the Plan. They do not in any way affect the amount of any benefit or pension payment, or the manner in which payments will be made to employees who become entitled to them. In the opinion of this Committee the changes will more effectually carry out the purposes of the Plan."

In accordance with these changes, the balance in the Employees' Benefit Fund at June 30, 1928, in the amount of $184,775.79 has been transferred to the Pension Fund.

During 1928 total payments under the Plan for Employees' Pensions, Disability Benefits and Death Benefits amounted to $107,675 as follows:

Pensions	$ 5,324
Accident disability and death payments...	9,823
Sickness disability payments	84,868
Sickness death payments	7,660
Total	$107,675

A. F. WEBER, *Secretary*,
Employees' Benefit Committee.

The above statement of payments audited and found correct.

E. J. SANTRY,
General Auditor.

News Notes

DR. JEWETT, together with O. E. Buckley of the Laboratories and Lloyd Espenschied and T. G. Miller of A. T. & T., sailed for Europe on February 9.

ON FEBRUARY 7 Dr. Jewett was a guest of a group of University of Chicago Alumni at a dinner at the Metropolitan Club, where he described the developments which resulted in the present transatlantic radio telephone circuits.

DR. JEWETT will read a paper at the World Engineering Congress in Tokio, Japan, late this year.

THE RECEPTION COMMITTEE at the Edison Medal Presentation included G. F. Fowler, Chairman; H. S. Black, D. G. Blattner, W. G. Laskey, D. E. Trucksess, and J. F. Wentz.

AT THE FEBRUARY 4 MEETING of the Colloquium, R. R. RIESZ spoke on the "Theory of Operation of the Human Larynx." On February 18, W. Wilson addressed the Colloquium on "Physical Problems of Radio."

THOMAS I. STARR, Assistant News Manager of the Michigan Bell Telephone Company, was a recent visitor to the Laboratories. At that time he stated that whenever a new telephone building is constructed in his territory, among the papers placed in the corner-stone box for preservation is a copy of the booklet, "Pictures from Bell Telephone Laboratories."

APPARATUS DEVELOPMENT

F. F. LUCAS spoke on "Metallographic Studies of Steel" before the Buffalo Chapter of the American Society for Steel Treating on January 24.

H. A. ANDERSON addressed the Educational Group of the Consolidated Gas, Electric Light and Power Company in Baltimore on February 5, on "New Developments in Engineering Materials."

W. J. FARMER visited Baker and Company in Newark for discussion of manufacturing procedure in rolling thin duralumin ribbons.

J. R. TOWNSEND attended a meeting of the Fatigue Committee of the American Society for Testing Materials in Philadelphia.

H. N. VAN DEUSEN visited New Orleans and other southern cities in an inspection survey of telephone exchange apparatus of the Bell System.

D. W. MATHISON visited Lansing, Michigan, during the week of February 11 in connection with the cleaning of step-by-step switches in dial offices.

R. M. PEASE gave a demonstration in connection with a lecture by S. P. Grace before the Cincinnati Engineering Society and the local section of the A.I.E.E. on January 17.

D. M. TERRY spoke on television before the Men's Club of the Methodist Episcopal Church of Elmhurst, Long Island, on January 15.

H. F. DOBBIN and H. BROADWELL were at Hawthorne during the week of February 4 to discuss tool-made samples of precision interrupters.

H. S. PRICE made surveys for one-kilowatt broadcasting equipments

purchased by the Outlet Company of Providence, Rhode Island, and by the Shepard Stores, Boston. He also inspected the 500-watt equipment owned by the Edison Electric Illuminating Company of Boston.

B. R. COLE supervised the installation of a crystal-control conversion unit for the one-kilowatt broadcasting equipment owned by the Acme Mills of Hopkinsville, Kentucky. He supervised the installation of a one-kilowatt broadcasting equipment and associated speech input equipment for the Memphis Commercial Appeal at Memphis, Tennessee, and made a survey for the proposed five-kilowatt installation to be owned by the Atlanta Journal, Atlanta, Georgia.

E. L. NELSON is a member of the group preparing the program for the discussion of radio achievements at the World Engineering Congress to be held in Tokio next October.

INSPECTION ENGINEERING

A. F. GILSON AND E. G. D. PATERSON visited Hubbard and Company at Pittsburgh, Madison Foundry Company at Cleveland, and National Fireproofing Company at Aultman, Ohio, to make studies of inspection and quality-control methods as applied in the manufacture of various outside plant materials.

R. B. MILLER visited Philadelphia on January 23 to discuss an inspection plan for panel central offices based on the "Defect Tolerance and Sampling Requirements Specifications" which have recently been completed.

O. S. MARKUSON visited Kearny during the week of January 28, and R. M. Moody and H. C. Cunningham visited Hawthorne during the week of February 11, in connection with regular survey conferences.

A. N. JEFFRIES visited Electrical Research Products, Incorporated, in Philadelphia on several occasions to investigate apparatus for the production and exhibition of synchronized sound pictures.

G. D. EDWARDS, A. G. DALTON AND I. W. WHITESIDE, Philadelphia Field Engineer, visited Washington, Philadelphia, Harrisburg and Pittsburgh in connection with Field Engineering activities, during the week of January 20.

PATENT

MEMBERS OF THE PATENT DEPARTMENT who went to Washington during the period from January 11 to February 9 were: E. W. Adams, W. C. Kiesel, A. G. Kingman, G. C. Lord, R. G. Mullee, O. E. Rasmussen, J. W. Schmied, and G. H. Stevenson.

During October, November, December and January, applications for patent were granted to the following members of the Laboratories staff:

B. G. Björnson
H. S. Black
W. T. Booth
O. E. Buckley (3)
W. W. Carpenter (2)
E. H. Clark
R. D. Conway
E. B. Craft
A. M. Curtis (4)
H. F. Dodge
J. B. Draper
G. H. Duhnkrack
B. G. Dunham
G. W. Elmen
J. F. Farrington (3)
H. A. Frederick
E. W. Gent
J. J. Gilbert (3)
W. S. Gorton
A. E. Hague (2)
R. W. Harper
J. E. Harris
H. C. Harrison
R. V. L. Hartley
J. F. Hearn
R. A. Heising (9)
E. E. Hinrichsen (2)
C. L. Hippensteel
J. F. D. Hoge
H. E. Ives (3)
K. S. Johnson
L. H. Johnson
W. C. Jones
C. R. Keith
B. W. Kendall (3)
F. A. Korn
J. J. Kuhn (2)
F. R. Lamberty
M. B. Long
G. R. Lum (4)
E. R. Lundius
A. C. Magrath
W. A. Marrison
R. C. Mathes (5)
D. D. Miller
C. R. Moore
E. R. Morton
W. E. Mougey (2)
P. B. Murphy
E. L. Nelson
H. W. O'Neill (3)
A. A. Oswald (2)
E. Peterson (3)
A. Raynsford
V. L. Ronci (2)
F. M. Ryan
J. P. Schafer
J. W. Schmied
E. E. Schumacher
P. Schwerin

W. J. Shackelton	A. L. Thuras
E. B. Smith	J. F. Toomey
W. F. Smith, Jr.	E. C. Wente
A. B. Sperry	E. B. Wheeler (2)
C. A. Sprague	J. H. White
F. A. Stearn	R. R. Williams
R. L. Stokely (2)	S. B. Williams
H. M. Stoller (2)	I. G. Wilson
C. F. Swasey	E. B. Wood
D. M. Terry	A. W. Ziegler

Systems Development

L. M. Allen attended the cut-over of the new step-by-step equipment at Hartford, Connecticut, on January 12.

H. C. Caverly and O. H. Kopp discussed sender test circuits with representatives of the Hawthorne Works and the Michigan Bell Telephone Company.

A. E. Bachelet, B. A. Fairweather and K. Lutomirski visited various repeater stations on the Pittsburgh-New York cable, to make tests on the new B-22 program supply circuits.

J. R. P. Goller visited the Allentown, Pennsylvania, repeater station to supervise the installation of electrolytic condensers.

H. E. Marting and E. H. Smith visited the new step-by-step dial office in process of installation at Wilmington, Delaware.

R. H. Miller and R. G. Koontz discussed the new No. 3 toll board at Detroit with engineers of the Michigan Bell Telephone Company.

L. A. O'Brien has returned from England, where he supervised the installation of a picture transmission system for the Daily Express Newspapers at their offices in London, Manchester and Glasgow.

L. F. Porter conducted tests on the new No. 3 toll board which will shortly be placed on service in Chicago.

T. A. Spencer conferred with representatives of the Western Electric Company in Chicago on equipment to be used in testing the new No. 3 toll board.

Charles N. Fenstermacher, supervisor of a circuit analyzation group in the Systems Development Department, died on February 24. Mr. Fenstermacher had been associated with the Bell System since July 18, 1904.

Research

A. C. Keller and I. S. Rafuse visited the Veeder Root Manufacturing Company in regard to the manufacture of special magnetic counters used in electric recording of sound.

H. A. Larlee attended a meeting of the Instruments Committee at Hawthorne from January 28 to February 2, discussing current engineering on transmitters and receivers.

R. M. Burns visited Norfolk, Atlanta, Birmingham and New Orleans from January 3 to 15 for a survey of the corrosion of telephone apparatus.

L. H. Campbell visited New Haven to observe shop application of automobile finishes. He later investigated cable corrosion at Elkton, Maryland, and Wilmington, Delaware.

B. L. Clarke was in Norfolk and Baltimore from January 27 to 29, continuing studies of cable corrosion started last July.

Harvey Fletcher attended meetings of the American Federation of Organizations for the Hard of Hearing at Washington, over the week-end of February 2.

Dr. Fletcher, J. B. Kelley and J. C. Steinberg attended the Second Conference on Research for the Deaf and Hard of Hearing held under the auspices of the Division of Anthro-

pology and Psychology of the National Research Council.

E. C. WENTE made observations in connection with commercial sound films in Hollywood, California, from January 9 to 30.

E. F. KINGSBURY addressed the Ridgeview Community Men's Club of West Orange on television, on February 18.

AUTHORS OF PAPERS presented at the joint meeting of the American Physical Society and the Optical Society of America on February 23 included H. E. Ives, whose paper "Motion Pictures in Relief" was given. R. M. Bozorth gave a paper on "The Barkhausen Effect in Iron, Nickel and Permalloy." O. E. Buckley was the co-author with L. W. McKeehan, formerly of the Laboratories and now Director of Sloan Physical Laboratory of Yale University, of "Atomic Order in Ferromagnetism."

GENERAL STAFF

L. S. O'ROARK spoke on "The Photoelectric Cell and Its Uses in Communication" at Armour Institute, Chicago, on February 14, and on the following day at Northwestern University, Evanston.

J. O. PERRINE spoke on the same subject before the Milwaukee Section of the A.I.E.E. on February 18, and the Madison, Wisconsin, Section on February 19. Mr. Perrine subsequently spoke at the University of Illinois, Purdue University and the University of Michigan.

S. P. GRACE's lecture engagements included an address before the Nebraska Telephone Association at Lincoln on February 14, and one before the Nebraska Section of the A.I.E.E. and Engineers' Club of Omaha on February 19.

BELL LABORATORIES RECORD was represented by P. B. Findley at a conference of Bell System magazine editors held at 195 Broadway from February 25 to 28. P. C. Jones and A. R. Thompson attended certain sessions of the conference. On March 1, the out-of-town members made an inspection tour of the Laboratories.

M. B. LONG addressed the Philadelphia Section of the A.I.E.E. on January 14, being assisted in a demonstration of sound pictures by R. A. Deller.

A FEATURE OF THE WINTER CONVENTION of the A. I. E. E. was a lecture and demonstration in the Auditorium on January 30. S. P. Grace explained recent developments of these Laboratories, and R. M. Pease had charge of the apparatus used.

DURING FEBRUARY, nine laboratories men visited colleges and universities in the east and the middle west to choose future engineers for the Bell System from the 1929 technical graduates. M. B. Long was at Minnesota, Iowa State, and Iowa; R. A. Deller, at New York University and Ohio State; M. L. Wilson, at Lafayette; D. A. Quarles, at Lehigh; E. L. Nelson, at the University of Chicago, Armour and Northwestern; T. E. Shea, at Worcester; T. C. Fry, at Brown; W. Wilson, at Cornell; R. J. Heffner, at California Institute of Technology, Pomona, University of California, and U. of California, Southern Branch; and E. J. Johnson, at North Carolina Agricultural and Engineering, University of North Carolina and Davidson.

Club Notes

The Spring Entertainment and Dance will be held in the Grand Ballroom of the Hotel Pennsylvania on Friday, April 26. The feature of the evening is to be a concert by our Glee Club, commencing at nine o'clock. Dancing to the mellifluous cadences of Herbert Hood's orchestra will last from ten till two.

The Glee Club has been rehearsing since last October, under the leadership of Professor V. S. Richards, to produce a "concord of sweet sounds" for this occasion. Ada Van Riper and P. H. Betts, who have been acting as business managers of the club, have been no less diligent in aiding Professor Richards with the musical direction.



General admission tickets include a seat for the concert, and cost one dollar. Box seats are two dollars each, and should be reserved early to avoid disappointment. Reservations may be made by calling D. D. Haggerty on Extension 542.

Basketball

Year after year the many branches of the Bell System in the metropolitan district strive to build up a basketball team that will beat West Street but each year the results are the same. The Laboratories' cagers are out on top: undisputed champions of the Bell System.

On Monday evening, February 11, West Street won the Bell System League championship when they defeated the team representing the Southern Division of the New York Telephone Company, Manhattan. This game completed the League season during which the Laboratories' team played nine games, winning eight games and defeating the strongest teams that the New York Telephone Company and the Western Electric Company could put on the courts.



Two exceptionally strong teams stood between the Laboratories and the championship but our players met each organization and sent them home with the short end of the score. On Monday evening, January 21, one of these games was played with the New York Telephone Company, Long Island Division. After a fast, hard and clean game we won by a score of thirty-four to nineteen. On Friday evening, February 1, our team played its annual game with the team from Western Electric, Hudson Street, with three hundred seventy rooters from West Street on hand to cheer our players. When the final whistle blew the score was twenty to thirteen in favor of West Street. This was the tenth of a series of annual engagements with Hudson Street, all of them won by our team.

The heavy work during the season fell on C. F. Gittenberger, C. Maurer, W. Steinmetz, H. D. Cahill and C. Christ, with C. Kirsch and J. E. Keogh as substitutes. With the exception of Christ, who was a substitute on last year's team, the other regular players have represented the Laboratories in outside competition for the past seven years. Carl Maurer was the outstanding star on the team and also won the Robert Stoll trophy for the most points scored by an individual in league games. Maurer finished the season with one hundred and nineteen points, a player from Western Electric Company, Installation Department team being a close second with one hundred and twelve points. Cahill, who played as guard, was considered one of the best defensive players in the league, and Gittenberger had no equal as a center. Christ and Steinmetz also share credit for points scored by the team.

In winning the League championship the Laboratories now have two legs on the league trophy, which must be won three times for permanent possession. The members of the team will receive from the League prizes valued at one hundred dollars.

Cartoonists' Contest

A monthly contest for cartoonists will be held by the Bell Laboratories Club. A prize of five dollars will be given each month for the best cartoon.

Cartoons must follow these general rules.

1. The size must be 5¼ in. by 8 in. or of such proportions that the picture can be reduced to this size.
2. There must be no lettering on the cartoon.
3. There should be no text over the cartoon; the picture must explain itself.
4. Likeness may be realistic enough to be effective but no personal peculiarities are to be ridiculed.
5. Laugh *with* your subject, not *at* him.
6. The cartoon may be worked in "black and white," "outline," "crayon," or "wash."
7. Cartoons may be a single subject or progressive action to an end.
8. Cartoons are to be submitted to D. D. Haggerty, Room 164, before or on the fifth of each month. The subject for each month will be announced in the preceding issue of the Record. The contest begins in April, when the subject will be bowling, and cartoonists will have an opportunity on Friday evenings, March 8, 15, and 29, to study and sketch their subjects. The bowling league meets at Dwyers Manhattan Alleys, 1680 Broadway, from 5:45 P. M. until 8:15 P. M. on the evenings mentioned.

Bowling

With the crashing of pins instead of guns, the battle of one hundred and sixty bowlers has been fought each Friday evening since September 28, 1928, with the front line trenches at Broadway and 53rd Street. The objective of this battle is the top of the "average" column instead of Paris.



In Company A, three month's fight has been waged for the leadership between T. C. Rice and H. C. Dieffenbach with Dieffenbach now

leading by seventeen pins or .5 of a point in the averages. In Company B the fight for leadership is just as close. F. Lohmeyer is leading with 168.85 but is being pushed hard by F. S. Entz who has a season's average ot 167.92. A. G. Kobylarz has the undisputed right to first place in C Company with an average of 160.24 but in D Company the fight is a close one between W. R. Steeneck and L. B. Taylor, whose averages are 147.69 and 147 respectively.



A cartoonist looks at bowling and bowlers

A split in the tenth frame of the last game on Friday evening, February 8th, prevented the Ringers in Group A from breaking the present league high team score of 1005. While the Ringers hold this record score they are always working with the idea of bettering it. The split in the tenth resulted in a total team score for the game of 994, which in itself is an exceptional score for an industrial league. On the same night this team broke the league record for total pins for three games when they finished with a total of 2,761 pins.

On December 21st, W. A. Bollinger won the fountain pen donated by A. F. Gilson, the general chairman, for the bowler who exceeded his season's average by the greatest number of pins. The competition for this prize was exceedingly close and the following is the final standing for the first five men:

W. A. Bollinger, C League, improvement—38 pins

H. La Frenz, D League, improvement—36.91 pins

T. J. O'Neil, A League, improvement—36.85 pins

H. A. Reybert, C League, improvement—34.69 pins

A. G. Jeffrey, B League, improvement—34.63 pins.

The fight for high score honors has been close throughout the entire season and the leadership of this group has been changing continually. At the present time P. B. Fairlamb holds high score in A with 256. R. S. Wilbur is leading B with 247. H. A. Reybert has taken first place in C with 236 and H. A. Paulssen is now leading D with 221.

Although the bowling committee is more than pleased with the general improvement of the bowlers, the fact that there has been a one hundred per cent attendance for eighteen weeks makes them feel that they have been compensated for the work of carrying on the activities of the league.

Glee Club

On January 30, the members of

the Glee Club, accompanied by Professor Richards and Mrs. Richards enjoyed a dinner party at the Ship Shape Inn. Returning to the Laboratories after dinner, the members played various games until time for rehearsal. The vocalists then reverted to the serious business of practicing for the concert, which will precede the Spring Dance of the Club on April 26.

Women's Swimming

To those of us who are unable to get to Palm Beach this winter (and aren't we all!) — the swimming classes at the Carroll Club are a neat solution to the problem of getting in some swimming during the winter months. The temperature in the pool is artfully regulated to afford a semi-tropical atmosphere. If the more conservative of the swimmers still find the water a trifle chilly, a few strokes of the Australian crawl will soon remedy that. Miss Spranger's pupils are now nearly all able to do the crawl, by the way, and most of them have learned a thing or two about plain or fancy diving. This last item appeals especially to persons who have yearned to enter the water in a more graceful way than holding one's nose, and jumping in, feet first.

Details as to time, place, and all that, will be most amiably furnished by Catherine Tully, on extension 218.

Women's Bowling

The season's prizes for the women's group of the bowling league, now on exhibition in the show case, are adding incentive to keen competition among the women bowlers. The awards include a prize for the greatest improvement in average, donated by A. F. Gilson, General Chairman of the League. Joe Dusheck appears on the scene every Friday evening to coach the team. His suggestions and friendly criticism are greatly appreciated by the Club. The Bowling League is planning to give a dinner and theatre party at a date to be announced shortly.

Club Calendar for March

FRIDAY, 1: Bowling, Dwyers Manhattan Alleys, 5:45
Bridge, Women, 11th floor Rest Room, 5:10

SATURDAY, 2: Commercial Chess League Tournament, Men, Brooklyn Edison vs. B. T. L., 463 West Street, 2:00

MONDAY, 4: Bridge Tournament, Men, Western Electric Co. vs. B. T. L., 195 Broadway, 6:30
Dance Orchestra Rehearsal, 11th floor Rest Room, 5:30

TUESDAY, 5: Handball Tournament, Men, Labor Temple, 5:30
Orchestra Rehearsal, 11th floor Rest Room, 6:00

WEDNESDAY, 6: Glee Club, 11th floor Rest Room, 5:10
Swimming Class, Women, Carroll Club, 5:30

THURSDAY, 7: Handball Tournament, Men, Labor Temple, 5:30

FRIDAY, 8: Bridge Tournament, Women, W. E. Co. vs. B. T. L., 195 Broadway, 6:30
Bowling, Dwyers Manhattan Alleys, 5:45

MONDAY, 11: Bridge, Men, Room 275, 6:00
Dance Orchestra Rehearsal, 11th floor Rest Room, 5:30

TUESDAY, 12: Handball Tournament, Men, Labor Temple, 5:30
Orchestra Rehearsal, 11th floor Rest Room, 6:00

WEDNESDAY, 13: Glee Club, 11th floor Rest Room, 5:10
Swimming Class, Women, Carroll Club, 5:30
Indoor Golf Tournament for Men, Miniature Golf Course of America, 5:30

THURSDAY, 14: Handball Tournament, Men, Labor Temple, 5:30

FRIDAY, 15: Bowling, Dwyers Manhattan Alleys, 5:45
Bridge, Women, 11th floor Rest Room, 5:10

SATURDAY, 16: Commercial Chess League Tournament, Men, Western Union vs. B. T. L., 195 Broadway, 2:00

MONDAY, 18: Bridge, Men, Room 275, 6:00
Dance Orchestra Rehearsal, 11th floor Rest Room, 5:30

TUESDAY, 19: Handball Tournament, Men, Labor Temple, 5:30
Orchestra Rehearsal, 11th floor Rest Room, 6:00

WEDNESDAY, 20: Glee Club, 11th floor Rest Room, 5:10

THURSDAY, 21: Handball Tournamen, Men, Labor Temple, 5:30

FRIDAY, 22: Bowling, Dwyers Manhattan Alleys, 5:45
Bridge, Women, 11th floor Rest Room, 5:10

MONDAY, 25: Bridge, Men, Room 275, 6:00
Dance Orchestra Rehearsal, 11th floor Rest Room, 5:30

TUESDAY, 26: Handball Tournamen, Men, Labor Temple, 5:30
Orchestra Rehearsal, 11th floor Rest Room, 6:00

WEDNESDAY, 27: Glee Club, 11th floor Rest Room, 5:10

THURSDAY, 28: Handball Tournamen, Men, Labor Temple, 5:30

FRIDAY, 29: Bowling, Dwyers Manhattan Alleys, 5:45

SATURDAY, 30: Commercial Chess League Tournament, Men, B. T. L. vs. Chase National Bank, 463 West Street, 2:00

BELL LABORATORIES RECORD

TEXTILES
AS INSULATORS

RADIO
FOR AIRPLANES

STRAIGHTFORWARD
TRUNKING

APRIL 1929 VOL. 7 NO. 8

Bell Laboratories Record

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Bell Laboratories Record

Volume Seven APRIL, 1929 *Number Eight*

Textiles as Insulators

By A. C. WALKER
Research Department

THE insulation resistance of most solid dielectrics is greatly reduced if moisture is absorbed on their surfaces or penetrates into their internal structure. Gutta percha, the classical insulation of submarine cable, absorbs at most one or two per cent moisture when actually immersed in sea water, and the change in electrical properties is very slight. Rubber insulations absorb but a few per cent moisture under similar conditions, and when used in air are practically unaffected by atmospheric humidity. On the other hand textile insulations, largely because their threadlike structure gives a much greater ratio of surface to volume, absorb from twenty to thirty per cent of their weight when exposed to an atmosphere of very high relative humidity. With changes in humidity, their water contents change rapidly, and their dielectric properties reflect the influence of absorbed moisture.

Among the textiles, silk has been used for many years as an insulating material on electrical apparatus because of its recognized superiority in insulation resistance over cheaper fibrous materials such as cotton. This property of silk is rather surprising in light of the fact that the amount of moisture absorbed by it under given atmospheric conditions is greater than that absorbed by cotton.

Several years ago these observations suggested that a study of the effect of moisture on textiles, sufficiently thorough to explain this apparent contradiction, might discover means of treating the cheaper vegetable fibers so as to obtain superior insulating properties.

In determining the insulating properties of textile materials, experiment has shown that at least three factors are important. They are: the quantity and distribution of water in the fibrous structure; the amount and kind of water-soluble electrolytic impurities which are present, either naturally or as contaminants; and the kind of fiber—cellulose, protein, or other chemical species.

Between a textile and its surrounding atmosphere, moisture tends to pass until an equilibrium is reached

between the moisture content of the textile and the relative humidity of the atmosphere. The moisture content of each sort of textile then depends directly upon the relative humidity of the atmosphere. Figure 1 shows this relation for several types of fibrous materials—cotton, silk, wool, and cellulous acetate. This orderly dependence of moisture content on relative humidity is similarly reflected in the relation between relative humidity and electrical characteristics. Figure 2 shows the insulation resistance of these materials plotted against per cent relative humidity over a limited range. It is impracticable to plot the resistance over the whole humidity range in this direct way, because of the wide variation of insulation resistance. The entirety of the data can, however, be shown by semi-logarithmic plot (Figure 3).

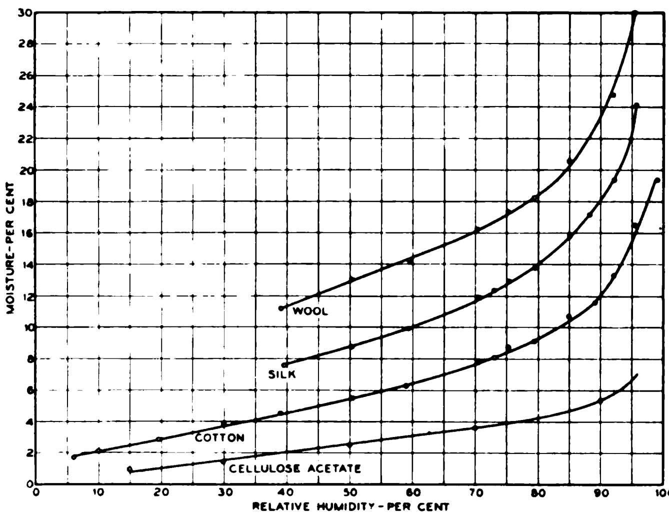


Fig. 1—Dependence of moisture of textiles upon relative humidity of atmosphere with which they are in equilibrium

Considered together, these three figures show that the insulation resistance of fibrous materials depend upon their moisture contents, and that these in turn depend upon the atmospheric relative humidity to which the materials are exposed. A misconception sometimes arises that the moisture contents, and therefore the electrical properties, of dielectrics depend upon the absolute humidity. In fact, however, the actual quantity of water vapor present in the air—the absolute humidity—bears

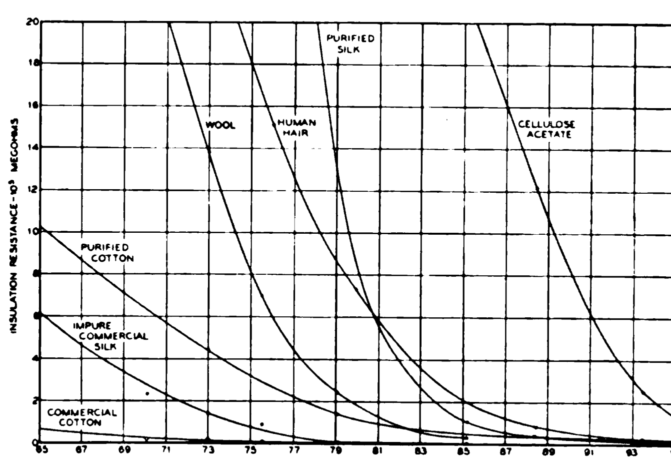


Fig. 2—Insulation resistance of one-half-inch lengths of textile threads as affected by relative humidity of atmosphere

little relation to the moisture content of textiles; it is the degree of saturation of the atmosphere with water vapor — the relative humidity — that bears the significant relation.

Polarization, another well-known phenomenon, is also found in the electrical behavior of textiles. If any dielectric be brought into contact with two electrodes of opposite polarity in the presence of atmospheric moisture, the electrical properties of the material undergo change with a rapidity dependent on the current and hence on the voltage, the length of the path, and the humidity. Such changes in the properties of insulating materials with continued applications of voltage have been considered accountable to the presence of electrolytic impurities in the materials. But the great magnitude of this change, from tenfold to a hundredfold increase in the insulation resistance of textiles exposed to ordinary humidities, has been very little appreciated.

The rise in resistance appears to be largely due to the partial removal of electrolytic impurities from some intermediate portion of the fiber to the vicinity of the electrodes. This can be strikingly shown by reducing polarized and unpolarized textile threads to ash. The ash of cotton, for example, is composed of salts largely of potassium, in some part of sodium, and to a less extent of calcium, magnesium, iron and aluminum. When organic materials containing small amounts of salts of the alkali metals, sodium and potassium, are ignited, the alkali salts melt at a relatively low temperature and protect the carbonized organic residue. This property is particularly advantageous in the study of the ash structure of polarized cotton threads, displaying the regions containing mineral constituents as those in which a black ash is preserved. If polarized cotton threads are ashed, the larger part of the mineral constituents are found in the neighborhood of the electrodes,

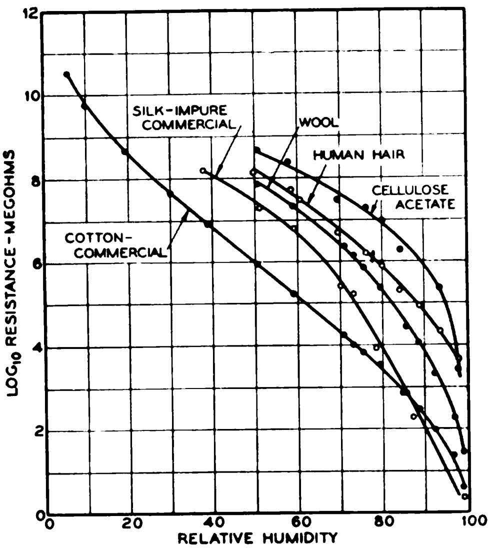


Fig. 3—*Logarithmic plot of the data of Fig.* 2

particularly the cathode. The cathode region is found to be alkaline, the anode region acidic.

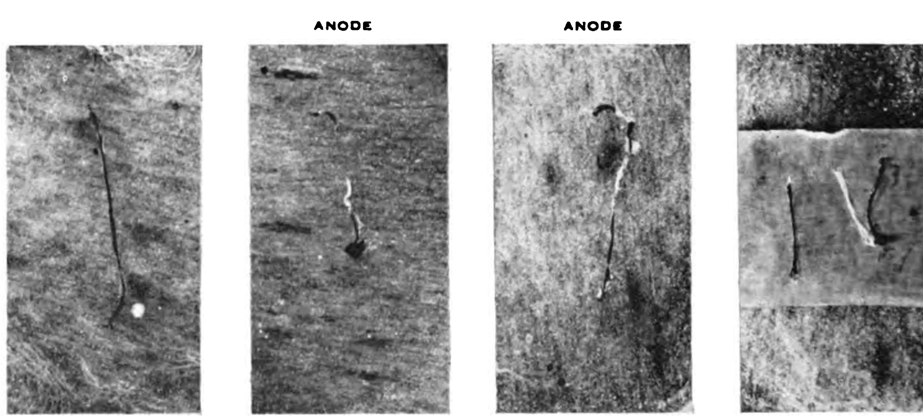
Figure 4 shows the ash of a short piece of raw cotton thread. The blackened structure shows the presence of small amounts of alkali salts uniformly distributed throughout the fibrous structure. Figure 5 shows the ash of a similar length of cotton which was subjected to a polarizing potential of one hundred volts, and exposed to a relative humidity of ninety-eight per cent, for several days. A large part of the ash constituents have migrated to the negative electrode portion, leaving a short section entirely free of ash. The ash of Figure 6 is that of another similar length of the same polarized cotton thread which was permitted to remain at

ninety-eight per cent relative humidity for several weeks after the polarizing potential was removed. The mineral constituents have to a considerable extent returned along the thread.

To verify the fact that the blackening effect could be due to the alkali salts, note in Figure 7 the ash structure of three different samples of cotton: the first of untreated raw cotton, the second of a well-washed thread of the same material, the third of a thread which was well washed, then dipped in a dilute solution of sodium hydroxide. The presence of alkali is clearly indicated in the first and third threads, but not in the second. This is to be expected, since it is well known that practically all of the alkali salts are easily removed by a simple washing treatment with water.

Perhaps the most significant evidence of the importance of electrolytic impurities in silk, wool, cotton, and to some extent other textiles, is the improvement of their electrical characteristics by thorough washing with water, without qualitative alteration of the general nature of the electro-conducting phenomena which characterize them. Figure 2 illustrates the result, on their insulation resistance, of washing cotton and silk threads. Fiftyfold to a hundredfold improvements in insulation resistance correspond, in the case of cotton, to diminutions in ash content, from about one per cent to a quarter or a twentieth of this value. Little or no reduction takes place, over the ordinary ranges of atmospheric humidity, in the moisture content at equilibrium. The sensitivity of purified cotton to the continued application of voltage is much less than that of the raw, but polarization still occurs. Commercial silks are similarly affected by washing. The differences in ash content and improvement factor are in some cases much greater than for cotton, because silks practically always contain acids, alkalis and soaps as residues from a degumming treatment to suit the silk for spinning. Cotton of the type generally used for electrical insulation receives no treatment by water or aqueous solutions from the time it is picked until it is transformed into finished thread.

If the mineral contents of washed cotton are quantitatively compared with the original contents, a decrease is observed, considerable in potassium and less in calcium and magnesium. Fairly complete removal of potas-



Figs. 4, 5, 6 and 7—Photomicrographs of ashed threads

sium is apparently essential to good electrical characteristics, but electric improvement has been attended in some cases by an increase in the content of calcium and magnesium. This suggests that interchange of electrolytic impurities between the textile and the water takes place along with removal of electrolytes by the water.

When tests were made on a commercial scale at Hawthorne, to determine appropriate means of improving cotton by washing, cotton washed with water from Lake Michigan had better insulating properties than had been obtained in the laboratory with distilled water. Later tests with distilled water duplicated the Hawthorne tests in one or two cases, but in general Lake Michigan water gave uniformly superior results. Experiments to determine the suitability of water in the Kearny plant for the same purpose gave much lower insulation resistances than those obtained at Hawthorne. Analyses of the two waters showed that the sodium and potassium contents were higher, and the calcium and magnesium contents much lower, in the Kearny than in the Hawthorne water. Sufficient magnesium carbonate to make a saturated solution of this salt was then used, with encouraging results, in a washing experiment at Kearny. The use of calcium sulphate, a more soluble salt, in numerous subsequent tests has produced cotton with insulation resistance as high as was obtained with Lake Michigan water.

Since textiles are composed of fibers, the resistance of a thread or the serving on a wire might be expected to depend largely on the resistance between fibers. The fibers themselves, furthermore, have superficial irregularities, suggesting that the resistances of different fibers of the same material might be widely dissimilar. That neither expectation is the case appears from many experi-

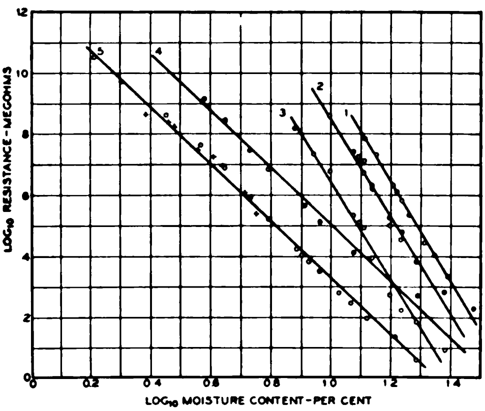


Fig. 8—Dependence of insulation resistance of textiles on moisture content 1—*Wool yarn,* 2—*Washed silk thread,* 3—*Unwashed silk thread,* 4—*Washed cotton thread,* 5—o *Unwashed cotton thread;* +*cellulose acetate thread*

ments with individual fibers and with threads.

Measured under controlled conditions of humidity and temperature, the insulation resistances of different single fibers are remarkably uniform. The insulation resistance of a thread, moreover, is practically that of all its component fibers in parallel, and contact resistances appear, therefore, to have negligible effect on the resistance of threads. This is true also for resistances measured transversely. Even when the length of a thread considerably exceeds the length of a single cotton fiber—about one inch—its resistance remains approximately proportional to its length. If interfiber resistance were large, the resistance per unit length would increase with the length of thread whose resistance was measured.

Thus for a given kind of fiber, the

more water and electrolytic matter present, the poorer are its insulating properties. But if these were the sole factors determining the electrical characteristics of all fibers, regardless of kind, animal fibers would be expected to be inferior to any of the species discussed. This is emphatically not the case; kind itself appears to be a factor. The vegetable fibers are inferior to the more hygroscopic animal fibers, and to the least hygroscopic synthetic fiber, cellulose acetate. To make clear the contrast, the logarithm of the insulation resistance is plotted against the logarithm of the moisture content in Figure 8; the values for each fiber fall approximately on straight lines throughout the range of measurement. The relative position of the curve for animal fibers, to the right and above that for cotton, means that the animal fibers have better insulating qualities in spite of their greater hygroscopicity.

The slopes of these lines have an even greater significance, for they indicate the sensitivity of the fibers to an increment of moisture. The steeper slope for the animal fibers indicates an electrical sensitivity to moisture greater than that of cotton. Under similar conditions they are not only wetter than cotton but more sensitive to further increments of moisture, yet they have a higher insulation resistance.

The differences in electrical behavior of the fiber species are believed accountable to differences in the spatial configurations according to which water is distributed within the individual fibers. The patterns are probably determined directly or indirectly by the chemical composition of the fibers and associated with the colloidal structure of the material.

As a result of our laboratory study cotton can now be improved in insulation resistance by simple washing operations to such an extent that it becomes an approved substitute in telephone cords* for all unwashed silk insulation. In this single respect a saving of several hundred thousand dollars per year is estimated, and the use of purified cotton in other places may materially increase this saving.

**The application of the results of these studies to the telephone plant is described by H. H. Glenn elsewhere in this issue of the* RECORD.

Washed Textile Insulation for Central-Office Wiring

By H. H. GLENN
Apparatus Development Department

SINCE the early days of telephone development work, silk and cotton have been the standard materials for insulating the wires in central office apparatus. In later years these materials have been supplemented by enamel. In general the insulation of the wires has been satisfactory, but breakdowns have occurred which could not be attributed to operating conditions or manufacture.

Studies made in these Laboratories revealed that impurities in the insulating textile—small quantities of water-soluble salts—were largely responsible for the observed irregularities. When moisture penetrates the textiles, as it always does in humid weather, these salts form weak aqueous solutions throughout the material, which by their conductivity reduce the insulation resistance of the textiles. Furthermore, the studies showed that passage of the leakage current through the solutions sets up a chemical reaction and the products of this reaction migrate to points of greatest current leakage. These products, themselves electrolytes, further increase leakage, and may ultimately lead to complete failure of the insulating textile, and even to serious corrosion of the metallic conductor itself.

The obvious procedure for improving the insulating properties of textiles is to remove the hazardous impurities. Since the contaminants are water-soluble, they can be abstracted by thoroughly washing the impure textiles with water. The process, however, purposes a substantially complete removal of salts already present in only small quantities, and must, therefore, use water of low saline content. The washing is best accomplished by a continual flow of water which, after one passage through the textile, is regarded as contaminated and is not used again. When the material is to be both dyed and washed, it can be washed, without intermediate drying, immediately after it has been dyed.

A comparison of the insulation resistances of cotton-insulated and silk-insulated wire at various relative humidities, ranging from sixty-five per cent upward to ninety per cent and down again to sixty-five per cent, before and after washing is shown in Figure 1. The improvement obtained in both silk and cotton by this process is seen to be marked.

A further requirement for the insulation is that the energy losses at speech and carrier-current frequencies be maintained at a minimum consistent with the space limitations applying to the conductors. The effect of purification of the textiles on this characteristic, expressed as loss in transmission units measured at 1000 cycles per second between the wires

of twisted pairs, is shown in Figure 2. Use of a like thickness of insulation in all cases puts these graphs on a comparable basis.

The most important conclusion to be read from the graphs, from an economic viewpoint, is that cotton can be improved by washing to such an extent that it becomes a better insulator than the commercial insulating silk in general use. The cost of washing silk and cotton is nominal, usually less than five per cent of the cost of the material. The engineer given purified textiles may either take advantage of marked improvement in electrical characteristics by using washed silk, or substitute washed cotton for unwashed silk and realize substantial economies without degrading the product.

Incorporation of the improved textiles in Bell System apparatus is proceeding rapidly. Central-office distributing-frame wire, of which the annual requirements exceed four hundred million conductor feet, is now insulated with two coverings of silk instead of the three formerly required. The resultant wire is electrically superior to its predecessor, and about seventy thousand pounds of silk are saved annually. Telephone cords of various types have been reduced con-

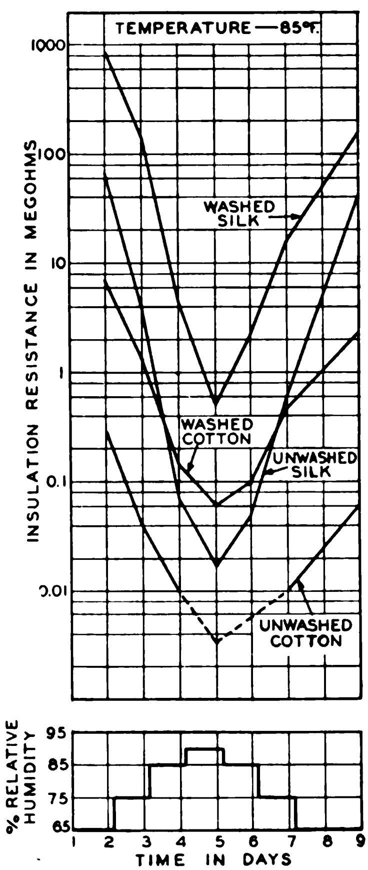


Fig. 1—D-c. insulation resistance of fifty feet of twisted pair wire insulated with double servings

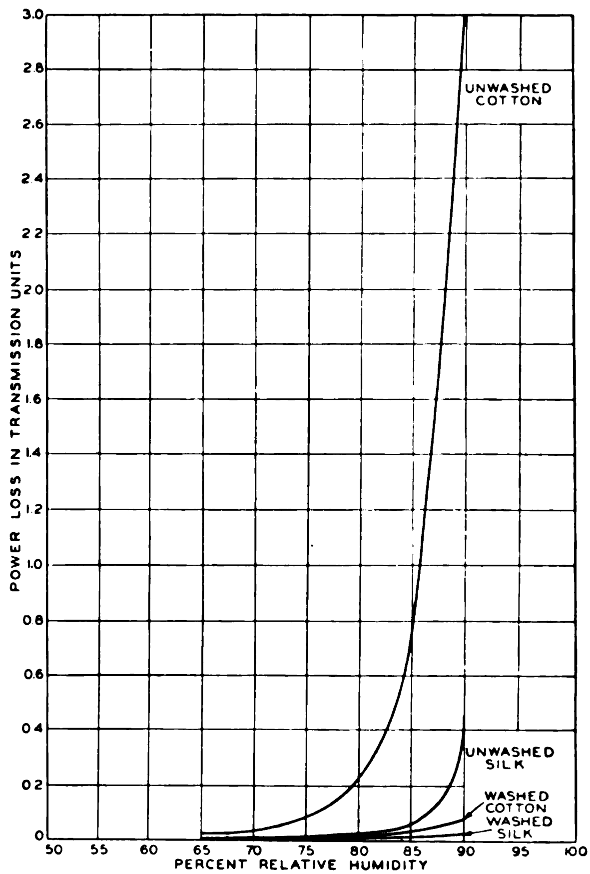


Fig. 2—Transmission loss in fifty feet of twisted pair wire insulated with double servings from measurements of a-c. conductance and capacitance

siderably in cost, without reduction in quality, by substituting two washed cotton braids for the cotton and silk braids formerly used. Corresponding economies in manufacturing cost or improvements in electrical properties

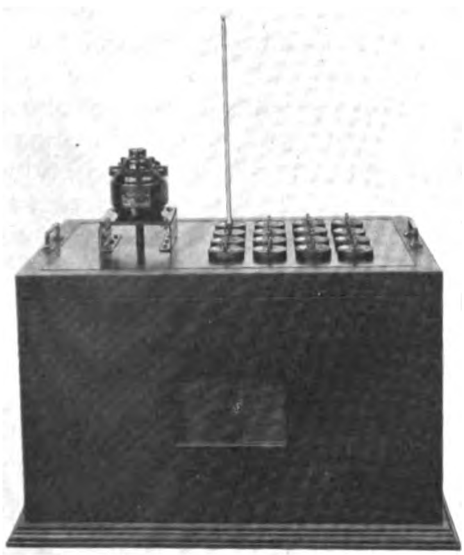


Fig. 3—Humidity cabinet for conditioning samples

will make the use of washed materials advantageous for various types of textile-insulated wire, exceeding two billion conductor feet in total annual requirements. Washed textiles are already incorporated in a large part of this output, and will be extended to the remainder as soon as possible.

To determine whether treated textiles have been washed sufficiently to meet established insulating requirements, their insulation resistance is tested in the factory before they are used. The development of apparatus sufficiently accurate for this purpose was a problem of considerable magnitude. Because the resistance of tetiles is quite high, delicate measuring instruments must be used, and the extreme sensitivity of textile resistance to changes in relative humidity requires that the humidity and temperature of the atmosphere enveloping the samples be closely controlled.

The apparatus at present used for factory testing is pictured in Figures 3 and 4. The sample of thread to be tested is dried in a dessicator to bring all samples to a common condition of moisture content, then wound in a single layer around two electrodes which are inserted in a hard-rubber stopper. The stopper is placed in one of the holes in an insulating lid covering a heat-insulated glass tank of about one cubic foot capacity. In this

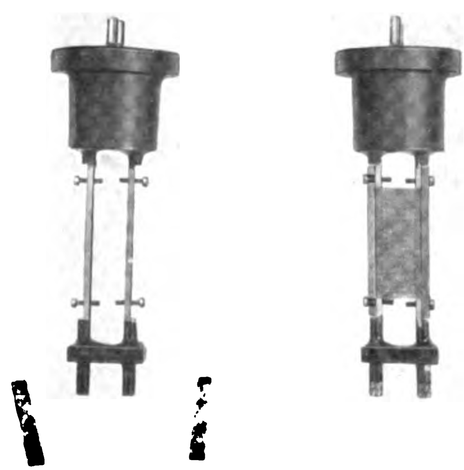


Fig. 4—Electrodes on which samples are wound for test

tank the humidity is accurately maintained, at seventy-five per cent for cotton testing and eighty-seven per cent for silk testing, by sulphuric acid or a saturated salt solution at the bottom of the tank,* and constant temperature is secured to within 0.05 degree F. by enclosing the assembly in a cabinet whose temperature is

* Bell Laboratories Record, *December*, 1927, page 108.

automatically controlled to within 0.1 degree Fahrenheit. The sample is equilibrated with the humidity over night, and its resistance is then measured. The separation of the electrodes and the number of turns of thread are such as to give readings of the order of 2000 megohms for washed silk and 1000 megohms for washed cotton and about one two-hundredth of these values for the respective unwashed textiles.

At high humidities there is still a wide margin between the insulating properties of washed silk and of washed cotton. Further study may reveal that this margin can be reduced. Laboratory experiments, in which cotton has occasionally shown improvement greatly exceeding the average, justify hope in the possibility of so processing cotton that its electrical properties will equal those of washed silk for many purposes.

Although there is still much to be learned about the electrical behavior of silk and cotton under various treatments and conditions, certain facts have been established beyond doubt. It is clear that the removal of the water-soluble salts which are present in both silk and cotton not only effects a decided improvement in their insulating properties but reduces the sensitivity of their alternating-current characteristics to changes in atmospheric relative humidity. The realizable improvement is great enough to permit the substitution of washed cotton for silk where commercial silk has been found to give satisfactory results. The use of purified textiles in switchboard cables carrying continuous direct potential will reduce electrolysis and thus prolong the useful life of the cables approximately in proportion to the extent to which the purifying process has been carried.

Laying A Foundation for Aircraft Communication

By D. K. MARTIN
Apparatus Development Department

AIR transportation requires for its fullest success a reliable and rapid means of communication with ground stations. The experience of air transport operators during the recent rapid expansion of the aviation industry has served to emphasize the necessity of such radio communication. With a deep appreciation of this need and a full realization of the difficulties of the task, Bell Telephone Laboratories has undertaken to develop equipment suitable for this service.

The first step in the development program was taken nearly two years ago when a thorough survey was made of the communication requirements of air transport. This was followed by the purchase of a Fairchild cabin monoplane with which extensive studies have been made under actual flying conditions. By the use of this plane, a better understanding has been obtained of the requirements of such a communication system, and a quantitative study has been made of transmitting conditions encountered in airplane operation.

Such transmission studies, including radio field-strength measurements, have been made for many years in



Fig. 1—The rod antenna and wind-driven generator may be seen in this photograph of the Laboratories' plane

connection with the engineering of broadcasting stations and of the transatlantic radio telephone circuits. In this work, however, data was required only of the transmission efficiency between two points on the earth's surface. For this new under-

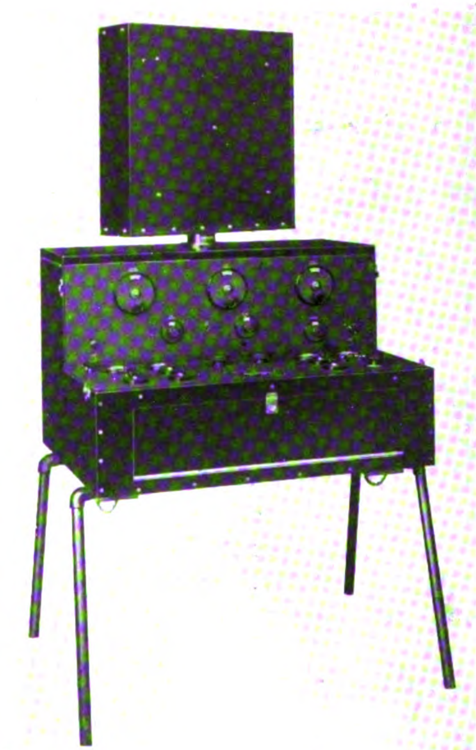


Fig. 2—Although the 44-A Test Set is designed for use with a loop, a rod antenna was used in the tests for reasons mentioned in the text

taking a third dimension, altitude, was involved and an additional difficulty was brought in due to the rapid change in position of the plane.

The first transmission measurements were made employing the Laboratories' plane, flying from Hadley Airport in New Jersey as a base. These tests were made in the frequency bands of from 285 to 315 and from 315 to 350 kilocycles which have been set aside for radio beacons and weather transmission service respectively. For measuring the signal received in the airplane, the Western Electric field-strength measuring set (44-A Test Set), of the type developed for use of the Department of Commerce, was employed. This instrument was adapted for use in the airplane by substituting a short vertical rod antenna for the loop usually employed. Similar tests were made on the Pacific coast by a field party in charge of R. S. Bair. The curve of Figure 4 is typical of the many obtained from these tests.

This particular curve is especially interesting as it shows the reduction in field strength encountered in mountainous country. From data of this kind, a determination has been made of the sensitivity necessary for an airplane radio receiver to make possible the dependable reception of beacon



Fig. 3—E. F. Brooke operating the 44-A Test Set in the Laboratories' plane

signals and weather broadcast transmitted by radio telephone. In general it was found that at these frequencies transmission conditions between ground and an airplane were not greatly different from those existing between two points on the ground.

It has long been appreciated that although a one-way radio telephone and beacon service may provide all the communication required for many of the smaller planes, a two-way communication system is essential to the operation of the larger transport planes, particularly when carrying passengers. It is very generally agreed among air transport operators that radio telephony should be employed rather than telegraphy for this dispatch service. The reasons for this are rather obvious. With the telephone no special training in signalling is required to allow information to be passed between dispatcher and pilot, and there is the additional advantage of having an immediate and personal assurance that the information has been received and understood. Of no less importance is the rapidity with which information may be transmitted with the telephone. It is expected that the dispatch system for the more important American air lines will develop in a manner similar to that of the railway systems, where telephony has long been widely used for dispatching.

An accurate knowledge of the transmission characteristics of that portion of the frequency spectrum available for this two-way service is the foundation upon which a system must be built. The second step in our development program consisted, therefore, in a quantitative transmission study covering the frequency range of from 1500 to 6000 kilocycles, a preliminary consideration of

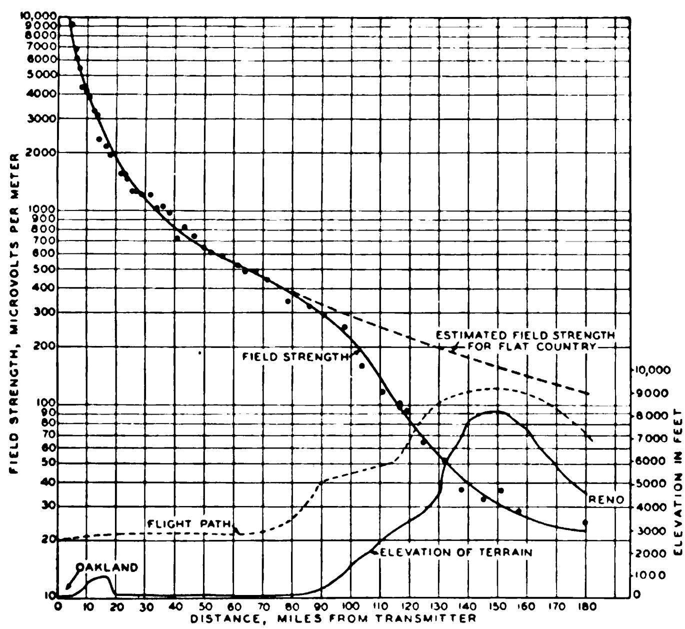


Fig. 4—Mountains decrease the intensity of signals received in a plane as they do those at land stations

the problem having indicated that this frequency range afforded the greatest possibility of any that could be employed without encroaching on other important radio services. In these tests transmission measurements were made both from plane to ground and from ground to plane—employing the field-strength measuring set in both cases. The curves of Figure 5 show graphically the results of one of these tests made at a fre-

quency of approximately 1600 kilocycles. These data were taken while transmitting from Bell Telephone

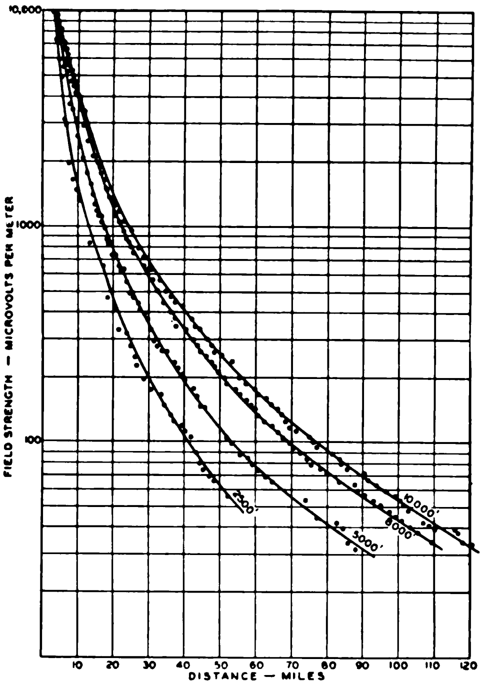


Fig. 5—Observations made indicate a considerable increase in signal strength as the altitude of the plane is increased. The altitude for each set of readings is indicated by the figures on the curves

Laboratories' experimental station at Whippany, New Jersey, and receiving in the airplane on a flight in the general direction of Baltimore.

These curves are typical of the large amount of data taken during flights in both the eastern and western experiments mentioned above. It will be noted that in contrast with the conditions found in the lower frequency band (285 to 350 kilocycles), the signal strength is a function of altitudes. Data taken at a frequency of approximately 5600 kilocycles at distances of from 30 to 40 miles showed the intensity of the signal to be approximately proportional to the elevation of the airplane, the signal increasing tenfold as the airplane height was increased from 1,000 to 10,000 feet. The field-strength measurements have been supplemented by quantitative intelligibility tests in which disconnected lists of words have been transmitted and a record kept of the accuracy of reception at the distant point.

The data obtained from these transmission tests have enabled the Laboratories to proceed with assurance to the design of a complete two-way radio telephone system for airplane dispatch service. The design of this apparatus has closely paralleled these transmission studies, and equipment is being designed for Western Electric manufacture which will adequately meet transmission requirements revealed by this survey. Regulatory requirements, such as that of the Federal Radio Commission decreeing that the transmitter be maintained to within .025 per cent of its assigned frequency, are also being fulfilled.

A New Radio Receiver for Commercial Airplanes

By F. M. RYAN
Apparatus Development Department

GOVERNMENT aids to air navigation now include not only emergency landing fields and beacon lights along the established airways, but also radio telephone stations for the hourly broadcast of weather conditions, and radio beacon stations for guiding airplanes in flight. Bell Telephone Laboratories, actively engaged in airplane-radio developments during the war, has been continuously at work in the radio field in the intervening years, and now to meet the demands of commercial flying has developed a new and compact radio receiving outfit known as the 6008-A, to be manufactured by the Western Electric Company.

Radio beacons, used to guide planes over the various airways now rapidly extending their branches over the country, operate in the band of frequencies from 285 to 315 kilocycles. Weather information is transmitted hourly from government stations in the frequency band from 315 to 350 kilocycles; and the new receiver is designed to cover these two bands, making it possible to tune to any beacon or weather transmitting station along the airways.

Requirements for a radio receiver for aircraft are exceedingly rigorous. The apparatus, employing only a small vertical antenna, must be highly sensitive to receive signals at distances of from 100 to 200 miles from two-kilowatt ground stations; it must provide sufficient output level to make the signals audible over the tremendous noise of engine, propeller, and wind, which is experienced in most present day planes; and it must, of course, be simple and dependable in operation. Compactness and lightness are additional requirements that can never be overlooked. All these requirements have been adequately met in the development of the new receiver.

Throughout the receiver, tubes of the recently developed unipotential-cathode type have been employed. The cathode of these tubes is not heated directly by the passage of a current but indirectly by conduction and radiation from an auxiliary filament. By this arrangement the possible introduction of noise from the filament supply is entirely eliminated. Only four tubes are used altogether. Three are of the shield-grid type, two being employed in the receiver as radio frequency amplifiers, and the third as a detector. The fourth, which does not contain the shield-grid feature, is employed as an audio-frequency amplifier.

There are three tuned circuits, one for the antenna, and one for the output circuit of each of the stages of radio-frequency amplification. A special gang condenser is employed

for simultaneously tuning these three circuits. In this way uni-control is provided with unusually compact and light equipment. The amplification of the receiver is controlled by a potentiometer which varies the shield po-



Figure 1—Simplicity of control, one of the many features built into the new airplane radio receiver, is evident from this photograph

tential of the two radio-frequency amplifier tubes. The only other control is a switch for turning the receiver on and off.

The receiver is mounted in a duralumin box about twelve inches long by eight high and a little over four inches deep. Complete with vacuum tubes it weighs less than thirteen pounds. The receiver is of high sensitivity; an antenna input of ten microvolts is sufficient to enable it to deliver an audio frequency output of six milliwatts. It is, however, capable of delivering output levels of as great as sixty milliwatts when required and, owing to the unusual detector characteristic, only twenty microvolts antenna input is required for this greater output.

Both filament and plate supplies are obtained from a small wind-driven generator with a stream-lined casing having a diameter of only a little over three inches. Complete with propeller it weighs less than seven pounds. This generator, driven at 6500 r.p.m. by a Deslauriers constant-speed propeller, is provided with a double winding, and supplies direct current at voltages of 9 and 220 for the filament and plate circuits. A filter for smoothing out the plate supply is included in the radio receiver. Due to the employment of vacuum tubes of the unipotential-cathode type, filtering of the filament or heater supply is unnecessary. The employment of this generator insures a dependable power supply at all times with a minimum amount of maintenance, and avoids entirely the use of dry batteries requiring frequent replacements. Mounting brackets and a connecting cable are provided with the outfit, which makes the installation of the generator in an airplane a relatively simple matter.

A stream-lined antenna pole about eight feet high is all the additional equipment that is required. The antenna may be either self-supporting or guyed, although the self-supporting type is preferred due to the smal-

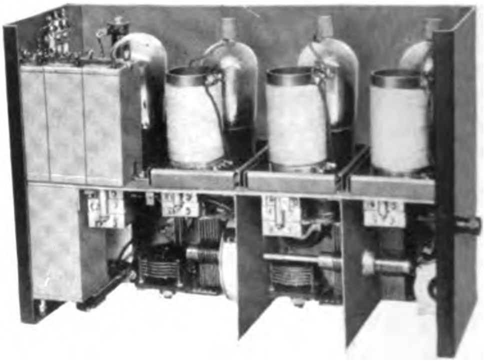


Figure 2—An interior view shows the compactness and relative simplicity of the apparatus

ler head resistance it offers. The only other special arrangements that are required to adapt the airplane for the use of this radio receiver is thorough

shielding of the ignition system. All the conductors must be carried either in rigid metal tubes or flexible braided copper sleeving, bonded at frequent intervals to the frame of the fuselage. The magneto and spark plugs must also be completely shielded. Magneto and engine manufacturers are now prepared to supply such completely shielded systems and shielded spark plugs are also available.

A low-impedance head set, equipped with a weatherproof cord suitable for use with standard Spalding radio helmets, is supplied with this outfit. This head set may be used by the pilot to receive both the weather and beacon signals now being transmitted from stations of the Department of Commerce. In receiving these beacon signals the pilot may determine to which side of the airway he is deviating by the relative strength of two Morse characters; when flying on the airway these characters blend into one long dash of constant amplitude. The radio receiver has been designed, however, to be used also with the visual type of beacon indicator advocated by the United States Bureau of Standards. If this type of beacon transmitter is adopted by the Light House Bureau, visual indicators of the vibrating-reed type will be provided for use with the receiver.

The general employment of this radio receiving outfit by air transport operators will make available to them, at a minimum of cost, the valuable aids to navigation which have been provided by the government. In many of the smaller ships at least this will be the only radio apparatus employed. Most of the larger ships, however, particularly those carrying passengers, will require complete two-way radio communication, and equipment for this purpose will shortly be available from the Western Electric Company as the result of extensive studies by Bell Telephone Laboratories.

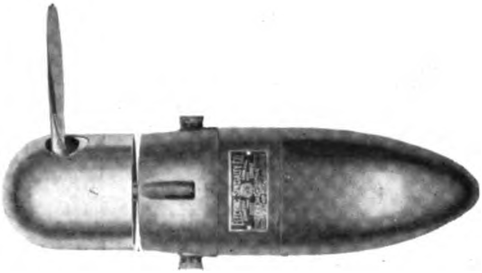


Figure 3—Only a single propellor blade is used with the wind-driven generator so as to simplify the adjustment of the blade angle to compensate for different velocities

Science in American

As long as the world at large was satisfied to leave the engineer and the scientist alone, they were content to communicate within their own ranks in their own language, and to bury within the volumes of their transactions their discoveries and deductions. But the day is past when it is right, or in fact possible, for the engineering story to lie hidden from the public. The sciences have entered so largely into business and into government that they have come directly into contact with millions of people who have no technical knowledge, but who still have the undisputed right to know at least something of what technical things mean. The people as a whole have signified their interest, too, and it is idle to continue to deny them information on the ground of their ignorance. Great stories lie hidden in science and engineering, and it is in line with the spirit of the times that these stories should become public property.

Because they lacked the time or because they felt it futile, technical men have never made an effort to explain themselves to their fellow human beings, and there has seldom been anyone else properly qualified to do it for them. The result has been unfortunate—bad for the public and bad for the profession, too. Great discoveries and inventions have lacked the public support; great projects have failed to interest those whom they were designed to serve; misunderstanding and misrepresentation, political corruption and large misuse of private power have grown out of the fogs that might have been dispelled by careful and enlightened publicity. In every profession there must be a certain number of people who are able to tell the story of the whole group to the outside world, and to promote within the group the exchange of thought and experience which helps to make the art progress.

—D. O. Woodbury in Tech Engineering News,
January, 1929.

Straightforward Trunking

By W. C. OAKES
Systems Development Department

A STRAIGHTFORWARD act is one in the accomplishment of which there is no retrograde action; it is one that advances orderly and progressively from beginning to end. So understood, the term straightforward is applicable to one method of operating trunks between telephone offices. While straightforward operation is practically as old as the scheme of trunking, having been employed on ring-down trunks or toll lines, and in isolated cases on automatic trunks, from the earliest days, yet it has not until recent years been developed so that it could be extensively applied.

Prior to the now general use of straightforward operation, the call-circuit method was commonly employed in establishing manual calls requiring trunking from one central-office district to another. Under this method, represented diagrammatically in Figure 1, the "A" operator, upon receiving a request for connection to a subscriber in another central-office district, depresses a call-circuit key bearing the designation of the called office. This operation connects her telephone circuit to a pair of conductors, known as a call circuit, which terminates at the called office in a "B" operator's telephone circuit, and over this call circuit she passes the number desired to the "B" operator. This operator in turn selects an idle trunk from the group running between the two central offices and assigns that trunk for the connection by passing its number to the "A" operator. The "A" operator then plugs the calling end of the cord used in answering the subscriber into the jack of the assigned trunk, while the "B" operator inserts the plug of the same trunk into the jack of the subscriber's line, thereby completing the connection.

Under straightforward operation, shown diagrammatically in Figure 2, the "A" operator upon receiving a request for a similar connection, herself selects an idle trunk which is then either manually or automatically connected to a "B" operator's telephone circuit. Two tone-impulses are returned over the trunk to the "A" operator to indicate that the "B" operator is ready to receive the call. Upon the receipt of the tone, the "A" operator passes the called number over the trunk and the "B" operator thereupon disconnects her tele-

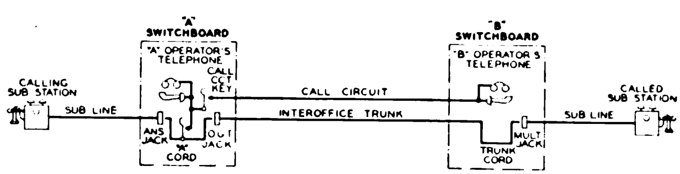


Fig. 1—Schematic of call-circuit interoffice connection

phone from the circuit and plugs the trunk into the called subscriber's line.

With the call-circuit method the choice of a trunk, as may be seen from the description above, is made by the "B" operator, while with the straightforward method it is made by the "A" operator. For straightforward trunking, therefore, equipment and operating methods must be provided for the "A" operator which she did not require when using the call-circuit method. Three ways of trunk selection* by the "A" operator are possible. The first is by the usual individual busy test and this method, in general, is found economical for groups of not more than twenty trunks. For groups containing twenty to fifty trunks, however, it is usually economical to employ a second method in which a master busy tone is used. The complete group of trunks to each office is divided into sub-groups of five and the operator determines whether all the trunks of a sub-group are busy by testing only the first trunk, the busy condition of the sub-group being indicated by a tone superimposed on the usual busy click.

For the third method, the trunk group is divided into sub-groups, as for the master busy tone, and a lamp is associated with each trunk. In operation, the lamp associated with the first idle trunk of a sub-group is

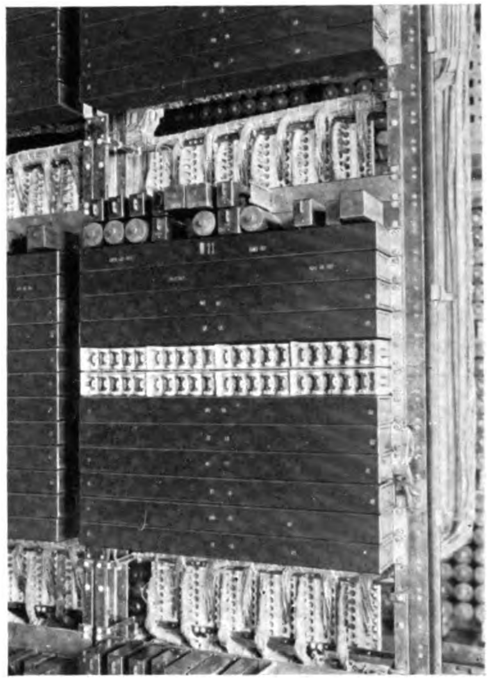


Fig. 3—An applique unit is a compact group of relays and equipment that contains the heart of the automatic listening system

lighted to indicate to the "A" operator the trunk which should be used. To permit the use of this scheme without sacrificing multiple space in the section of a switchboard, a combination lamp and designation strip has been developed which can be mounted in the space required for the usual designation strip alone. This method, known as "idle trunk indicating," is usually economical for groups of more than fifty trunks, but in some situations, such as with the "AB"

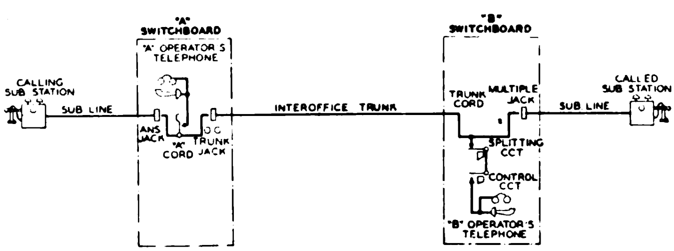


Fig. 2—Schematic of straightforward interoffice connection

* *A fourth method, used only for exceptional cases, was described in* Bell Laboratories Record, *Vol. VII, No. 4, pp. 157-160, December, 1928.*

tandem board, it is found desirable to use it with smaller groups.

As the "A" operator is responsible for selecting a trunk it is necessary to provide a means of indicating the selection to the "B" operator. The straightforward trunk has been arranged, therefore, so that the guard lamp at the "B" board will indicate when a call is waiting. Furthermore, in order that the "A" operator may pass the called number to the "B" operator under straightforward operation, provision must be made at the "B" board to connect the selected trunk to the "B" operator's telephone circuit. Three methods are possible, and they are known, in accordance with the practice employed, as jack-listening, key-listening, and automatic-listening operation. Automatic-listening operation is used in machine-ringing "B" boards and also in new tandem switchboards. Key listening, in general, is used in manual-ringing switchboards, while jack listening is employed in switchboards of which the expected life is too short or the trunks too few to justify the expense of either of the other methods.

With the jack-listening method the "B" operator plugs the trunk on which a signal appears, into the jack of a listening circuit at her position. The function of this circuit is to trip ringing in case machine ringing is employed, return the two-impulse order tone commonly known as a "zip" tone to the "A" operator, and immediately connect the trunk to the "B" operator's telephone circuit. As mentioned above, the tone informs the "A" operator that the "B" operator is ready to receive the call.

The key-listening method requires a key which is individual to a trunk, the "B" operator connecting her telephone circuit to a trunk by depressing the associated key. As with the other methods, the order tone is returned to the "A" operator to indicate that she should pass the call.

It will be noted that with both jack listening and key listening, the operation of connecting a trunk to the telephone circuit is under the manual control of the "B" operator. With automatic-listening operation, however, selected trunks are automatically connected to the "B" operator's telephone circuit one at a time, in a predetermined order advancing from left to right, as calls come in over them. The order tone is sent not only to the "A" operator but, on account of the automatic connection of the trunks to the telephone circuit, it is also returned to the "B" operator to inform her that a call is about to be passed.

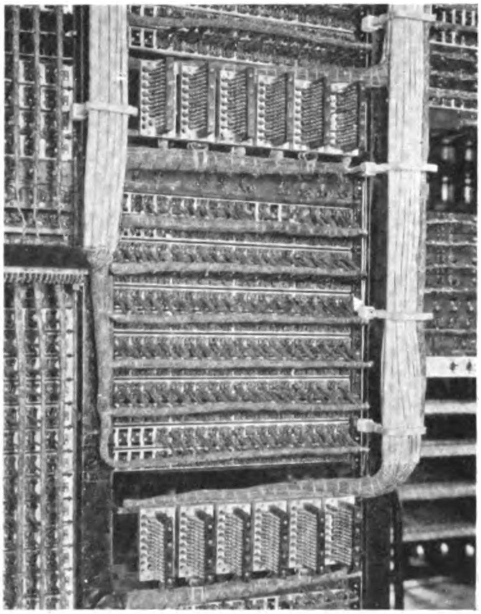


Fig. 4—A rear view of the applique unit emphasizes the compactness of the unit and the readiness with which it may be installed

The release of the trunk, however, is under the manual control of the "B" operator, and is accomplished by the depression of a release key or the plugging of the trunk into the line called. As the release of one trunk permits another trunk to seize the telephone circuit automatically, the release key is provided to permit the "B" operator to accept another call while the previous one is being plugged into a line jack. This overlapping operation speeds up service by filling the interval during which the operator is reaching for the jack.

Due to shortening the "B" operator's work-time the use of automatic listening has enabled the operators to handle a number of calls considerably in excess of those handled with the call-circuit method.* The key-listening method, although somewhat slower than that of automatic listening, also shows economies resulting from higher loads. Although the economies of jack listening over call-circuit operation are somewhat questionable, it is advisable, nevertheless, in a district which is being converted to straightforward operation to provide jack listening at the "B" boards of the few offices which can not be economically converted to key-listening or automatic-listening operation, in order to maintain a uniform operation on the part of the "A" operators.

The application of straightforward operation has been mainly to existing offices where the call-circuit method was in use. It was desirable, therefore, to engineer the requirements for the conversion so that a minimum of changes would be necessary in the existing equipment either on the relay racks or switchboards. The conversion required from one additional relay per trunk, for jack-listening operation, to four per trunk, for automatic-listening operation, with a further addition of from ten to fifty relays per position.

For automatic listening it was found that the most economical way of providing the extra equipment for the conversion was by supplying position units which included the extra relays for the trunks of a position as well as the relays for the positional circuits. This unit, shown in Figure 3, and known as the "applique" unit, is made up in the factory with all apparatus mounted and all wiring local to the unit permanently made. By proper cabling between the applique unit and both the existing relay racks and switchboards, the apparatus of the unit functions properly with the existing equipment to provide the traffic features of the straightforward method.

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* *With large groups this statement does not always hold but, considering areas as a whole, economies have always resulted, and uniformity of method warrants the change to straightforward trunking even in these exceptional situations.*

The Electromagnetic Oscillograph in the Circuit Laboratory

By L. J. STACY
Systems Development Department

OSCILLOGRAPHIC analyses as applied to problems of the Circuit Development Laboratory may be conveniently divided into three different types: measurements of time, including frequency and phase angle; investigations of wave shapes; and measurements of magnitudes of such quantities as current, voltage, power, resistance, inductance or capacity. So far it has been the practice to use the ordinary form of electromagnetic vibrating-mirror oscillograph modified to employ a special timing system, and a roll of recording photographic paper instead of a film and drum.

Time, in many cases, is the controlling factor in a telephone circuit. In a panel-type sender circuit, for instance, the relay which operates at each closure of the subscriber's dial contacts must operate within .025 second. Although it is possible to determine whether or not the relay operates properly by testing with a subscriber's dial or pulse machine, the oscillograph has been used to determine the margin of safety between the actual operating time of the relay and the minimum time allowed for operation in the circuit. At present, oscillograms are taken to measure operating and releasing times of relays; open and closed periods of interrupters; and many other allied conditions.

The timing system is controlled by an electrically driven tuning fork, adjusted to vibrate at the proper frequency, and carrying contacts which interrupt the direct current that operates a small impulse motor. A disk on the motor shaft has ten evenly spaced slits. Pulses of light admitted through these slits at regular intervals are directed by a suitable optical system to

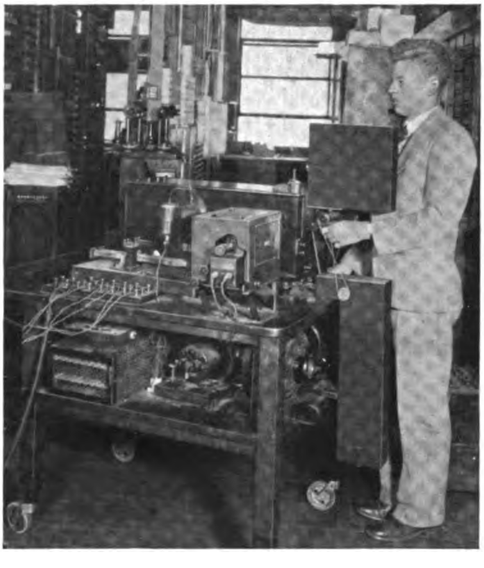


Fig. 1—Using the oscillograph to measure the operating times of relays

the edge of the film, where they form reference timing lines.

There are many factors to be taken into consideration, however, when measuring time with this instrument.

Among them are inherent limits of accuracy of the timing mechanism itself, such as small variations in the frequency of the timing fork and hunting of the timing motor; variations due to slipping of the paper; variation in the speed of the motor which, from a large roll, continuously draws the paper past the aperture; uneven shrinking of the paper during developing and drying; temperature variations causing changes in damping due to changes in the viscosity of the oil in the vibrator cell; and personal errors in reading the oscillograms. Fortunately most of these are not necessarily cumulative; some can be evaluated; and most of them can be kept small. The overall accuracy of the timing mechanism, checked by a thousand-cycle wave applied to one of the vibrators, is usually maintained to at least one-half of one per cent, and when necessary a much greater accuracy can be obtained.

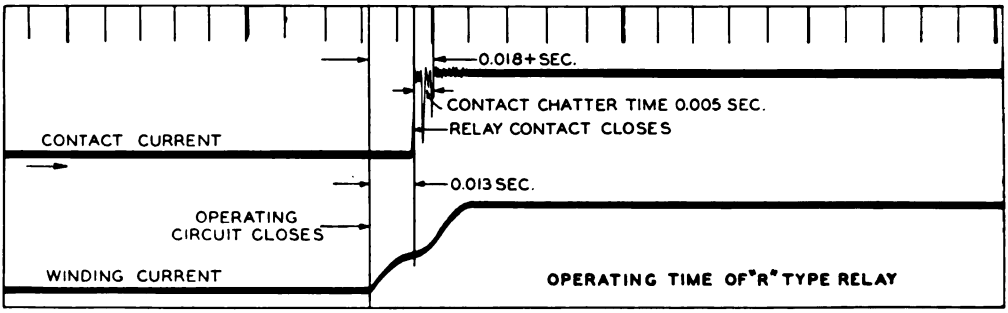


Fig. 2—Oscillogram illustrating the method of determining relay operating times

Inaccuracies resulting from unequal separation of timer lines have been observed to introduce an error in certain cases of from two to three per cent. Personal errors are difficult to evaluate but it has been demonstrated quite conclusively that individuals may vary in their readings of the same oscillogram by as much as five ten-thousandths of a second while readings made by the same individual will vary from day to day and even at different times of the same day.

In comparing wave shapes, oscillographs with vibrators having the highest natural period and critical damping are most satisfactory. Ringing and tone studies frequently require examination of the wave shapes from various machines, as changes in the shape of the current wave result in differences in the range and quality of the ring. So, too, the number and magnitude of the harmonics have considerable effect on the characteristic sound of a tone. Although the oscillograph gives no determinable quantitative measure of these harmonics it is frequently used to compare two waves with regard to general form.

In studies of clicks and other noises which may be produced in the receiver by various causes, wave shape is also examined by means of the oscillograph. Disturbances with wave fronts corresponding in steepness to those of a thousand-cycle sine wave will be much more objectionable than those with higher energy contents dissipated over longer periods, because both the receiver and the ear are most sensitive in the vicinity of a thousand cycles. With decreas-

ing frequencies the same energy becomes steadily less audible.

The most serious errors affecting the study of wave shapes are those caused by incorrect damping. Damping is controlled by the viscosity of the liquid—a mixture of oil and turpentine — in the vibrator cell. As viscosity is a function of the temperature, vibrators will be over-damped when cold and under-damped when hot. Wherever the wave form is at all important it is necessary to heat the field coils — the chief source of temperature rise — to such a point that the temperature remains substantially constant. The amount of damping can be adjusted by changing the proportions of oil and turpentine in the cells. Although there is a critical point at which vibrators show neither a lag nor an overthrow it cannot be maintained in practice. Fortunately damping does not require particular attention for the measurement of time intervals but as the vibrators are maintained just slightly under-damped when the fields are hot, there is a tendency to accentuate any contact chatter or similar conditions which may exist.

When quantitative measurements of current, voltage, or other quantities are to be made the vibrators are adjusted either to give known deflection for a predetermined circuit condition, or else to give satisfactory deflections for the unknown condition. In the latter case an additional calibrating picture would be taken with the same adjustment and a known current flowing. Under these conditions the oscillograph serves to record at each instant the value of current, voltage, power, or whatever circuit variable is being measured.

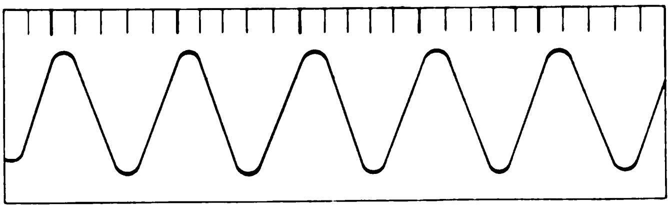


Fig. 3—Oscillogram showing the wave form of standard ringing machines

One of the interesting uses of the oscillograph for problems of this group is a method* of measuring the quantity of electricity required for any circuit operation. Oscillograms are taken of the current flowing in the

"Saving Days and Dollars with Shears" by S. W. Allison, BELL LABORATORIES RECORD, *January,* 1928.

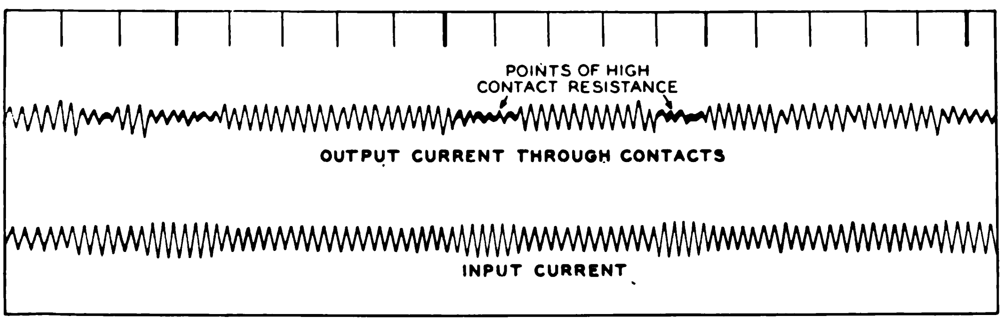


Fig. 4—Oscillogram showing the varying resistance of contacts

circuit for the period of operation. As the area under the current curve represents the energy consumed the area can be evaluated in ampere-seconds, and later translated into ampere-hour requirements of central-office batteries.

Another interesting use is measuring change in contact resistance in talking circuits with no direct current flowing. Oscillograms taken in the laboratory under these conditions show that the contact resistance varies over a wide range — becoming infinite and reducing the tone to zero in extreme cases. Special precautions must be taken to guard against such conditions in commercial circuits.

Errors in measuring magnitudes may be introduced by the causes already mentioned but more particularly by improperly damped vibrators. An over-damped vibrator is sluggish and the slope of the curve it traces— unless it be a steady-state value — is always less than the slope of the true curve. Under-damped vibrators overthrow and oscillate at their own natural period. True instantaneous values are not obtained unless the vibrator damping is critical.

The oscillograph may be applied to this great variety of circuit problems, but the engineer must recognize that like all measuring instruments it has limits of accuracy beyond which it is useless to go and that data obtained when these are ignored lead to results not always truly representative of what is occurring in the circuit.

"*Elementary Differential Equations*"

"Elementary Differential Equations," by T. C. Fry, has just been published by D. Van Nostrand Company. It becomes the most recent member of the Bell Telephone Laboratories series of books, of which the titles which have previously appeared are recapitulated on page 220 of the February RECORD. *Like its predecessors, the book is derived from out-of-hour courses given in the Laboratories by its author. It deals with the solution of ordinary differential equations and of systems of such equations, especially those linear equations commonly encountered in physics. The fundamental notions of differential equations are given geometrical interpretations which permit a ready visual grasp of their purport. Written primarily for engineers, the book avoids existence theorems and other topics of purely mathematical interest, and uses the space thus released for practical applications and illustrative examples.*

A New Cordless Switchboard

By W. O. FULLERTON
Systems Development Department

FOR small business establishments, even a complete and comprehensive telephone service may require comparatively few central-office lines and extension telephones. Except in the smallest organizations, a private branch exchange is generally desirable, however, to make any incoming call conveniently available to any of the employees, and to facilitate calls between the local telephones. It is especially necessary that switchboards for such installations take up a minimum of office space. Since the telephone calls seldom occupy the attendant's full time, the board should be arranged to allow her to carry on clerical or other work as well. Cordless switchboards, which occupy only a small part of the top of a desk or table, have therefore been made for many years, to provide the necessary switching facilities with the utmost compactness. As the name indicates, no switching cords are used; interconnections between extension telephones, and connection of these telephones to central-office lines for incoming and outgoing calls, are made by keys on the face of the switchboard.

At these boards there are terminated as many as three trunks from a central office and seven extension lines, in addition to the attendant's telephone. Each line, whether from the central office or from one of the extensions, terminates at a lever-type key made with three key handles. The handles can be operated both up and down, so that there are six positions available for each line. Five of these are used for connecting paths, so called—circuits within the switchboard, which join all the keys. Interconnection is secured by operating the keys of any two lines, to join them to the same connecting path. On a board fitted with the full number of lines, five conversations can be carried on at once—three to the outside, and the other two between extensions. Should the attendant not be involved in any of these calls, all seven of the extensions can be used simultaneously. The sixth key position is used for ringing, on the extension keys, and on the trunk keys for holding incoming calls until the desired line is free.



Fig. 1—Outer view of the 506-A switchboard. The other three pictures also show this switchboard

Since the necessary direct current

for talking and signalling is obtained through cable conductors running to the central office, it is desirable that current requirements be kept as low as possible. For this reason, and because the small number of lines makes simplification possible, electromechanical signals requiring little current are used for attracting the operator's attention in place of the signal lamps customary in switchboard practice. Above the key for each trunk circuit is a drop* operated by ringing current from the central office and restored by hand. Station line signals and supervisory signals are of the magnetic target type. Those for the extension lines are located above their respective keys; when a receiver is taken from the hook, the target of the corresponding signal appears, and it restores when the attendant answers. Supervisory signals are at the left of the key bank and opposite their respective connecting paths. They are displayed at the end of each conversation, after the extensions have hung up, and are restored when the attendant restores the keys to normal.

For ringing any of the extensions, pressing down the lowest handle of the appropriate key connects ringing current to the extension line. This current ordinarily comes from the central office, but when central-office ringing current is not available, a magneto generator built into the board is used.

On an incoming call from a central office, the drop associated with one of the trunks operates, and a buzzer gives audible notice that a call is waiting unless the buzzer is shut off at its control key. The attendant, choosing an idle path, connects it to the trunk and to her own telephone set by the appropriate key handles. On learning which station is wanted, she completes the call by connecting and ringing the desired station line. She disconnects her own telephone by restoring the key to its normal position, and when the call is finished restores both trunk key and extension key. Calls from one extension to another, or from one extension to the outside, are completed in practically the same manner.

When the switchboard is to be unattended, at night or at other times, three of the lines may be left connected to the trunks by operating keys just as for calls during the day. Calls may then be made and received directly at the

** Drops, the first visual telephone signals, have been made in many forms. As here used, they carry a shutter hinged at the bottom and held vertical by a latch at the top. Ringing current raises the latch, allowing the shutter to fall forward.*

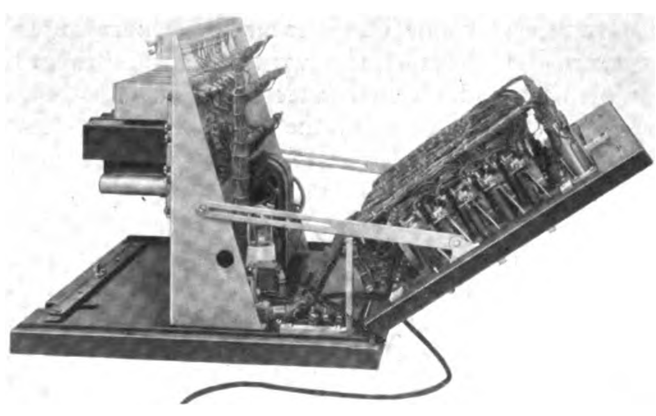


Fig. 2—When the cover is removed and the front swung down, ready access is given to all the apparatus

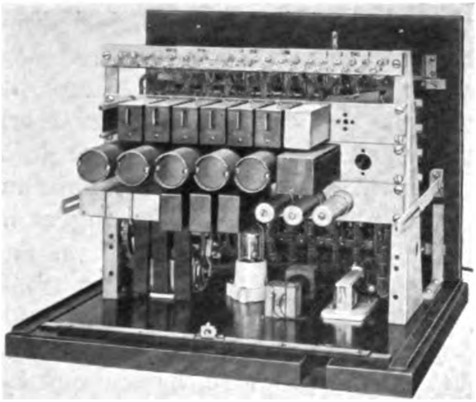


Fig. 3—The mounting-plate assembly is in the foreground, in this picture taken from the rear

extensions. The night service key is provided for use when these permanent night connections are set up. Its operation disconnects the battery from the supervisory signal circuits and opens the connection between the buzzer and the trunk drops, to prevent unnecessary battery drain.

Direct current for talking is supplied to local conversations through a retardation coil in each connecting path. To eliminate the transmission loss of these coils on outside calls, direct current in those cases is supplied from the central office over the talking circuit, and the retardation coils are cut out. This arrangement gives the local station the benefit of standard transmission on all central-office connections.

In the course of switchboard development the circuit features described had been provided a number of years ago. Now a new board of this type is being made, known as Number 506-A*. It is the same in circuits and in functioning as its predecessor, but in arrangement and mounting of the apparatus it has been revised completely to simplify manufacturing and to give maximum accessibility for maintenance. A salient feature of the new design, whereby the changed construction first becomes evident, is the type of cover, which includes roof, back, and two sides. When it is taken off, and the hinged front swung down as in Figure 2, the apparatus can be reached from all sides. The front itself has not been changed, but the apparatus mounted on the side walls of the older switchboard has been transferred to mounting plates on the interior, supported by two gusset plates of heavy sheet metal. Four pieces of apparatus—hand generator, resistance lamp, induction coil, and buzzer—are fastened to the wooden base, but everything else has been transferred to the

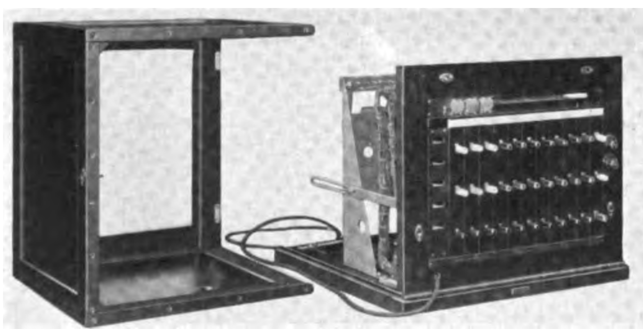


Fig. 4—The switchboard with cover removed, showing how readily the interior is made accessible

**Another new cordless switchboard, 506-B, gives switching facilities for five trunks and twelve extensions. In method of operation and circuit essentials it is the same as the smaller cordless P.B.X. Construction and arrangement of the apparatus are similar, but certain pieces of apparatus are mounted differently.*

mounting plates, except of course the apparatus mounted on the key front. At the top of the mounting-plate supports, where it is handiest, is a terminal strip for making connections to the central-office trunks and the extension lines.

Even removal and replacement of the cover have been simplified. It is open on the bottom and the front, and is arranged to fit against the back of the key front. A lock screw at the back, and two at the front, hold it in place. Steel runners at either side of the base, turned up at their outer edges, provide a surface on which the cover may slide, and prevent it from moving sidewise. A projecting strip at the bottom of the cover hooks under a metal strip running across the back edge of the base. As a result of this construction, removal or replacement of the cover, including unscrewing or replacing the three lock screws, is a matter only of seconds.

From the viewpoint of users and attendants, the distinguishing colors of the various groups of key handles facilitate operation by showing at a glance the grouping of the keys. At the same time identifying the keys has been made easier by an additional designation strip provided near the bottom, but otherwise the new switchboard has the same general appearance as that previously supplied. From the standpoint of installation and maintenance, however, it marks a prominent advance, giving greater speed for any necessary work as a result of the much greater convenience. Likewise the new construction, with everything so open and so readily accessible, facilitates manufacture.



It is with regret that we record the death of a valued member of our Technical Staff:

George Oliver Bassett

chemical engineer

August 24, 1870—March 21, 1929

Alumnus of Massachusetts Institute of Technology; member of the American Chemical Society; a member of the Bell System chemical staff since 1894, and in charge of the analytical laboratory since 1907; active in developing methods of analysis for paints and pigments, and in investigating means of wood preservation

News Notes

Mr. Charlesworth attended the Cincinnati Regional Meeting of the A. I. E. E. on March 20 and 21.

At the meeting of the Colloquium on March 4, K. K. Darrow discussed the "Fermi-Sommerfeld Theory of Electrons in Metals." R. L. Wegel spoke before the Colloquium on March 18 on the "Internal Viscosity of Metals."

The New York Chapter of the American Society for Steel Treating held its March 11 meeting in the Auditorium of the Laboratories. The guests, numbering about four hundred, were welcomed by G. F. Fowler, who introduced a showing of sound pictures. Following a talk by Dr. Ives, the television system was demonstrated. A tour of inspection was made of the Microscopical Laboratories directed by F. F. Lucas, who as Chairman of the Chapter arranged the meeting.

Research

H. D. Arnold addressed the faculty and senior students of the departments of physics and chemistry of Wesleyan University at Middletown, Connecticut, on training for engineering and research.

H. A. Frederick, W. C. Jones and H. A. Larlee attended a meeting of the Telephone Instrument Survey Committee at Hawthorne from February 24 to March 2, discussing matters pertaining to handsets.

L. H. Campbell and F. F. Farnsworth visited the Southern New England Telephone Company at New Haven from January 28 to February 1 to note the results of various types of finishes on automobiles used by the associated companies of the Bell System.

G. O. Bassett and R. E. Waterman made a general inspection of experimental tests on wood preservatives at Gulfport, Mississippi, from January 20 to February 16.

H. H. Lowry visited certain properties of the Lehigh Coal Company at Wilkes-Barre and Hazleton, Pennsylvania on February 5 and 6, and again on February 11, to investigate a new supply of coal for the manufacture of transmitter granules.

J. E. Harris and J. H. White were at Hawthorne from February 24 to March 3 to observe recent developments in copper refining.

Herbert E. Ives received the honorary degree of Doctor of Science from the University of Pennsylvania on February 22.

Harvey Fletcher recently gave a series of demonstration lectures on "How and What We Hear," speaking before the University Club of Chicago on March 9, at the University of Minnesota on March 11, and the Mayo Clinic, Rochester, Minnesota, on March 12.

General Staff

S. P. Grace spoke before the University Club of Albany on March 6 on recent developments of these Laboratories. The following day he addressed the executive and supervisory staffs of the New York Telephone

Children" before the Maxwell Training School Annex in Brooklyn on March 12.



1929 *Group of M.I.T. Students*

M. I. T. Students

Two groups of Massachusetts Institute of Technology cooperative students left the Laboratories to return to the Institute on February 1, 1929. One group will be graduated with the degree of master of science in electrical engineering in June of this year. They will have had five terms' experience in the Bell System in addition to completing all the courses required at the Massachusetts Institute of Technology for the master's degree. They are, left to right: standing, C. H. Rumpel, D. Y. Bradshaw, J. C. Edgar; seated, N. C. Olmstead, J. L. Barnes, J. E. Tully, C. T. Prendergast. This is part of the first group to be graduated under the Bell System option of the electrical engineering cooperative course.

The other group is a year behind the first. They are scheduled to re-

Company in Albany. On March 15 he addressed the Detroit Engineering Society and on the sixteenth, the executive and supervisory staffs of the Michigan Bell Telephone Company at Detroit. Mr. Grace also spoke before the College of Engineering at the University of Michigan on March 19. His engagements for March concluded with a speech at the Alumni Dinner of Massachusetts Institute of Technology at the Waldorf-Astoria, New York, on March 26. On each occasion, R. M. Pease demonstrated certain Laboratories apparatus in conjunction with Mr. Grace's talks.

John Mills addressed the Eastern Association of Physics Teachers at Boston on March 2, on the photoelectric cell and its use in communication. G. F. Fowler was also present, giving a demonstration of apparatus.

P. B. Findley spoke on "Speech and Hearing with Reference to Deafened School



1930 *Group of M.I.T. Students*

ceive their master's degrees from the Institute in June, 1930. They are, left to right: standing, W. C. G. Swift, O. R. Garfield, G. L. McKenna; seated, D. T. Osgood, R. D. Fracassi, L. R. Moses, A. E. Fribance.

* * *

M. B. LONG visited the state universities of Iowa, Nebraska, and Michigan, and Massachusetts Institute of Technology, during March to interview those of the 1929 engineering graduates interested in employment in the Bell System. During the month R. A. Deller went to Case, Purdue, and Virginia P. I. for the same purpose; M. L. Wilson, to Columbia; L. S. O'Roark, to Illinois and Kentucky; D. A. Quarles, to Union and Yale; E. L. Nelson, to Bradley; T. E. Shea, to Stevens, Syracuse, and Johns Hopkins; T. C. Fry, to Wisconsin and Harvard; W. Wilson, to Cornell and Princeton; E. J. Johnson, to Rutgers and Rensselaer; H. S. Shope, to Texas A. & M., Texas U., Rice, Oklahoma A. & M., and Oklahoma U.; and J. O. Perrine, to Pennsylvania State, Vanderbilt, Kansas U., Kansas State, Missouri, and Washington University.

APPARATUS DEVELOPMENT

R. L. JONES AND W. FONDILLER were recent visitors at Hawthorne, where they observed improved manufacturing processes now in use in the Manufacturing Department.

N. BISHOP inspected the five-kilowatt broadcasting equipment owned by the City of Atlantic City. With A. B. Bailey, he also supervised the conversion to crystal control of the five-kilowatt equipment at Station WABC of the Columbia Broadcasting System. Previously, Mr. Bishop had supervised the crystal-control conversion of the one-kilowatt broadcasting equipments at Miami Beach, Florida, owned by the Miami Beach Bay Shore Company and at Clay Center, Nebraska, owned by M. M. Johnson and Company. He installed a five-kilowatt broadcasting equipment at Tulsa, Oklahoma, recently purchased by the Southwestern Sales Corporation of that city. He also inspected the five-kilowatt equipment owned by the Bankers Life Insurance Company of Des Moines, Iowa, and the five-kilowatt equipment at Winnipeg owned by the Manitoba Telephone Systems.

W. L. TIERNEY supervised the conversion to crystal control of a one-kilowatt broadcasting equipment for Warner Brothers, Los Angeles, and a similar equipment owned by L. Wasmer, Inc., Spokane, Washington. In addition he directed the installation of a one-kilowatt broadcasting equipment for the Puget Sound Radio Broadcasting Company of Seattle. Mr. Tierney also directed the installation of the five-kilowatt broadcasting equipment for Hale Brothers, of San Francisco, California.

B. R. COLE made a survey for a one-kilowatt broadcasting equipment for the Matheson Radio Company, Inc. of Gloucester, Massachusetts.

J. C. HERBER directed the installation of five-kilowatt broadcasting equipments for the Alabama Polytechnic Institute and the State Government of Alabama. He also installed the associated speech-input equipment at Birmingham and Montgomery. He inspected the 500-watt broadcasting station WSMB of the Saenger Amusement Company of New Orleans, and the one-kilowatt broadcasting equipment owned by the City of Camden, New Jersey. Mr.

Herber subsequently made a survey for the one-kilowatt broadcasting equipment purchased by the Shepard Stores, Boston, Massachusetts. He also made an inspection of the 100-watt equipment owned by the Tremont Temple Baptist Church of Boston.

O. W. Towner supervised the conversion to crystal control of the five-kilowatt broadcasting equipments of the Peoples Pulpit Association, and the Chicago Daily News, Chicago; the Palmer School of Chiropractic of Davenport, Iowa; and the Zion Industries of Zion, Illinois. He also made a survey for a one-kilowatt broadcasting equipment for the Hotel Lassen of Wichita, Kansas. Previous to this, he had supervised the conversion to crystal control of the five-kilowatt broadcasting equipment owned by the City of Atlantic City, New Jersey, and the five-kilowatt equipment owned by the Radiophone Broadcasting Company of Chicago, and took part in the survey for the Shepard Stores of Boston, Massachusetts.

H. S. Price addressed the Graybar Convention of Specialists on February 14 on broadcasting equipment and surveys for installation.

R. V. Terry visited Washington and Rochester to inspect recording lenses for newsreel cameras.

G. Puller visited several motion-picture theatres in Philadelphia to inspect sound-picture apparatus.

R. Nordenswan spent several days at Hawthorne in connection with the manufacture of phonograph reproducers used with sound pictures.

E. G. D. Paterson, C. S. Gordon and A. F. Gilson visited the Chesebоro-Whitman Company in Newark Valley, New York, on March 4, and Mr. Paterson and Mr. Gordon visited the Babcock Company in Bath, New York, on March 5 to discuss the manufacture of ladders.

B. Freile visited Hawthorne and the Automatic Electric Company plant at Chicago during the week of February 25 to confer on step-by-step apparatus.

J. T. Butterfield has been elected President of the Passaic County Planning Commission, charged with coordinating the future growth of municipalities and suburban territories in his district.

A. F. Gilson visited the Stromberg-Carlson Manufacturing Company in Rochester and the Highway Trailer Company in Edgerton, Wisconsin, during the last week in February in connection with inspection engineering work.

Mr. Gilson was elected to membership in Edward J. Hall Chapter, Telephone Pioneers of America.

P. S. Olmstead attended a survey conference on handsets at Hawthorne and W. A. Boyd and R. M. Moody attended a similar conference on keys at Kearny during the last week in February.

R. J. Nossaman visited Field Engineering Headquarters in St. Louis, Cleveland, Detroit and Chicago and attended Field Review Conferences in Fargo, North Dakota, Minneapolis and Omaha during the latter part of February.

J. M. Hardesty attended the meetings of the American Concrete Institute at Detroit from February 12 to 14.

C. R. Moore visited Philadelphia on February 1 with H. D. Bender of the A.T.&T. Company to confer with the engineer in charge of standards of the Pennsylvania Railroad on

the standardization of outside-plant tools. They also visited the plant of North Brothers in Philadelphia to observe the manufacture of wood-bit braces.

S. C. MILLER was in Georgia and Florida during the latter part of February on matters pertaining to timber preservation.

E. H. COLLEY AND G. Q. LUMSDEN inspected the experimental test grounds of the Bell System at Gulfport, Mississippi, to compare the effects of various preservative treatments on telephone poles.

PATENT

I. MACDONALD, M. R. MCKENNEY AND P. C. SMITH were recent visitors to Washington in connection with the prosecution of patents.

SYSTEMS DEVELOPMENT

A. F. DIXON visited Hawthorne, where he observed many of the improved processes now in use in the Manufacturing Department.

R. S. WILBUR, J. R. STONE AND G. A. BENSON inspected the new No. 3 Toll Board at Chicago. Mr. Benson and L. F. Porter will remain during the test period and be present at the cutover.

W. J. LACERTE is spending several weeks at Denver, Colorado, in connection with the introduction of dial equipment in that city.

F. A. KORN, L. M. ALLEN AND H. A. MILOCHE visited the new Marine Office at Atlantic City and the new unattended exchange at Somers Point, New Jersey.

J. W. WOODARD discussed the new Akron toll project with engineers of the Ohio Bell Telephone Company at Cleveland and Columbus.

J. H. SOLE recently tested a new automatic voltage regulator at the A. T. & T. repeater station in Boston.

A. A. BURGESS supervised the installation of a new switched telephone typewriter service in the toll office at Chicago.

E. J. JOHNSON spent several days at the Hawthorne Plant during the latter part of February.

Bell Laboratories Club

Members of the Bridge Clubs and guests attended a lecture on the game by Mr. Wilbur Whitehead, given in the Auditorium on February 25. Twenty tables were arranged about the platform, at which most of the audience took their places. At each table identical hands were dealt, bid and played. The same hands were again dealt, face up, and the bidding was discussed in great detail by Mr. Whitehead. His questions as to the



correct procedure were searching, and many of his comments provoked a laugh. During the playing of several games, Mr. Whitehead walked about observing, commenting and answering questions. Well-known commuters were seen to struggle feebly as each train-time approached—but so great was their interest that they stayed to learn all they could. The big laugh of the evening followed Mr. Whitehead's winning of a "plugged nickel" from D. A. Quarles after a dispute on one of the finer points of strategy.

Swimming and Gymnasium Class for Men

Each year the Club adds new activities to its social and athletic program. During the past year golf and bowling were organized for women and tennis for men. The Club now offers swimming and gymnasium classes for men at the Kittredge School of Sports. The first class started on Thursday evening, March 14, and will be held each Thursday evening for a period of ten weeks. The fee is $7.50 per person for the course of ten lessons, which consist of one-half hour swimming instruction and one-half hour gymnasium work at each meeting. If the membership so desire, the course will be extended to fifteen weeks.

When the formation of this class was first announced it was hoped that twenty-five men would be interested enough to enroll. Instead, the Club Secretary was swamped with applications and was obliged to increase the membership to thirty, making arrangements with the Kittredge School to start a second class on Tuesday evening, April 2.

D. D. Haggerty, Room 164, will furnish further details regarding these classes, and if enough men are interested a new class will be started on the completion of the present one.

Baseball

Reading the National and American League training camp news reminds one that it is time to get out the old uniform, oil up the pet glove and report to Manager Wood at Farmer's Oval, where tryouts will be held for places on the team which will represent the Laboratories in the

Bell System Baseball League. West Street athletes have reigned supreme for a number of years in all branches of sports except baseball. In 1926, the first year that the Bell System League was organized, West Street men won the league championship, but in 1927 and 1928 the New York Telephone Company team has pushed us into second place. Is there any reason why our team should not finish on top in 1929? None whatever if the ball players in West Street will report for practice and help Manager Wood organize what should be the crack team in the League.



Of the 1928 first string, Trottere, Christ, Koch, Lohmeyer, Drenkard and Gardner remain as a nucleus. We want to hear from college players, men who have played on high school teams and those semi-pro players who may play twilight ball without interference with their Saturday and Sunday contracts. Pitchers are particularly wanted. Tryouts and practice sessions will be held at Farmer's Oval, Fresh Pond Road, Brooklyn, on Saturdays, April 13, 20 and 27. The opening game in the league will be played on Monday evening, April 29, at Erasmus Field, Brooklyn, and will be followed by games on each evening of the week during May, June and July.

Outside of big league ball parks, Erasmus Field is the finest athletic field in the metropolitan district. The park has a grass infield, excellent club house, and locker facilities with hot and cold showers. The Club also provides transportation to the field on nights that the team is scheduled to play. D. D. Haggerty, Room 164, or H. O. Wood, 5A, will be pleased to give full information.

Again this year the Club will have an interdepartmental baseball league. These games will be played at Erasmus Field on Saturday afternoons during May, June and July. Two games will be played each Saturday.

Indoor Golf Tournament

Sixty-six players teed up in the seventh indoor golf tournament of Bell Laboratories Club. A surprise was in store for them; H. L. Edlind, youngest player of them all, walked away with a low gross of 79, two strokes less than par for the thirty-six holes of the qualifying round. Then followed round after round of match play, enlivened by the plop of balls into the water hazards and a near-fire when Tom Rice laid his cigarette on a "property" rock. The players were divided into eight groups according to their qualifying scores. Final matches resulted as follows: J. A. Burwell defeated J. R. Kidd 1 up; "Jack" Hillier defeated H. W. Wood 2 up and 1 to play; L. G. Hoyt defeated N. Thorn 4 up and 3 to play; G. E. Kellogg defeated W. L. Kidde 3 up and 1 to play; E. G. D. Patterson defeated W. F. Johnson 4 up and 3 to play; A. L. Johnsrud defeated P. B. Fairlamb 2 up and 1 to play; F. Canavan defeated E. K. Eberhardt 2 up and 1 to play; J. J. Hart defeated C. A. Sprague 1 up. The prizes were clubs, balls, and golf



accessories. Taking home a prize was an old story for most of the winners; L. G. Hoyt for the fifth time finished "inside the money."

Several of the matches were hotly contested; Sprague took his match away from Crews on the twentieth hole; Patterson beat Hall on the twenty-first; while it took five extra holes for Kidd to establish his superiority over Heydt.

L. P. Bartheld, chairman of the Club's athletic committee, officiated as starter, with J. C. Kennelty, newly elected chairman of the golf committee, assisting.

Women's Interests

Basketball

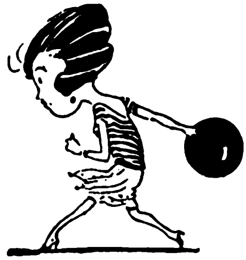
It is a matter of a great deal of pride to announce that the Bell Laboratories Women's Basketball Team has achieved first place in the Bell System League. Eight games were played and won by our team, five of them League games and the other three, outside games. Throughout these games the teams have met with a spirit of sportsmanlike competition and enthusiasm which probably began with the track meet and seems to be growing in all activities of the Club.



The prizes given by the League to the winning team were awarded to Ann Barioni, Marie Boman, Helen Fritschi, Marianne Grimm, Lillian Kaempffe, Marie O'Neill and Natalie Skinner.

Bowling

Perhaps it was the added incentive of a prize offered by A. F. Gilson coupled with a growing enthusiasm for the game; at any rate, Friday evening, March 1, at Dwyer's was the scene of much keen competition among the women bowlers. Antoinette Kelly was awarded the fountain pen and pencil for the greatest improvement over her season's average. Miss Kelly also leads with a season's high average of 104.3, followed closely by Natalie Skinner whose average is 99.5. Third place is held by Margaret Horne, average 94.1. The season's high scores, thus far, have been made by Lee Melita, 162, Antoinette Kelly 154, Natalie Skinner 152.



Dancing

Judging from the enthusiastic response made by the women of the Laboratories, the new class in rhythm is launched on what promises to be a very successful season under the direction of the Noyes School of Rhythm.

These evening classes are specially designed for business women to afford complete relaxation and to assist in acquiring graceful, rhythmic movement and correct posture.

The first class started Tuesday, March 12, and will continue every Tuesday till May 14.

Bridge

The Women's Bridge Club of Western Electric "GHQ" entertained the women of the Bell Telephone Laboratories at a tournament for the women's trophy on March 8. The evening's play ended very nicely for

the visitors, who kept the trophy for the Laboratories with a plus score of 4562.

The leaders in the tournament were:

Catherine Maull and
Katherine Munn 1963

Allegra Rodgers and
Elizabeth Pritzkow 1180

Thelma Taylor and
Edna Haunfelder 1170

These inter-club meetings are proving very popular and will undoubtedly be arranged more frequently in the future.

Hiking

Hiking season is here again.

Our Saturday walks are easy although the mileage may seem large. There is always a camp fire supper at the end of the hike.



On Sunday we go farther and harder. Hikers bring their own food on these long hikes; empty knapsacks may mean hungry mouths.

Weekday campfire suppers are heaps of fun. We leave the building at five sharp and cross the Hudson at Dyckman Street. Everyone pitches in and helps so that by seven o'clock we are all having a race to see who can make the clubbiest sandwich. We sit around the fire and after apologies to the moon and stars, we try to sing. A final cup of coffee and the last of the cookies and we start for the ferry. We always miss a boat because we have to stop at the kiddies' playground and "go up in the air so high." The hostess attends to the food supply and camp equipment for these suppers.

You can get a printed program from the hostess of the hiking activity, Phyllis Barton, Room 749-B.

Indoor Golf

A most successful indoor tournament was held at the Miniature Golf Course of America on Thursday evening, February 28.



In the qualifying round of medal play, thirty women teed off, of whom Miss I. H. Benedict had the low score, one hundred and six strokes. She was awarded an eight-dollar order on Peck and Peck. In the finals Miss Benedict was entered at scratch, and each of the others was given a handicap equal to three-quarters of the difference between her own score and that of Miss Benedict.

Marie Boman's net forty-eight in the finals was low enough to win the first prize, also an eight-dollar order on Peck and Peck; and Helen Cruger won a vanity box by turning in a net forty-nine for second place. Helen Norton finished in third with a net fifty and was awarded a scarf, and Amada Mancinelli received a compact for finishing in fourth place with a net score of fifty-one. Miss Menig's fifty-two was just one stroke too many to enter the charmed circle of prize winners. Miss Benedict's card for the final totalled fifty-seven.

The next tournament is scheduled for March 27. Marion Kane, who can be reached on 774, will furnish particulars.

Club Calendar for April

MONDAY, 1: Bridge, Men, Room 275, 6:00
Dance Orchestra, 11th floor Rest Room, 5:15.
Swimming Class, Women, Carroll Club, 7:00

TUESDAY, 2: Symphony Orchestra, 11th floor Rest Room, 6:00
Swimming and Gym. Class, Men, Kittredge School, 6:00

WEDNESDAY, 3: Glee Club, 11th floor Rest Room, 5:10
Swimming Class, Women, Carroll Club, 5:30

THURSDAY, 4: Swimming and Gym. Class, Men, Kittredge School, 6:00

FRIDAY, 5: Bowling, Dwyers Manhattan Alleys, 5:45

MONDAY, 8: Bridge, Men, Room 275, 6:00
Dance Orchestra, 11th floor Rest Room, 5:15.
Swimming Class, Women, Carroll Club, 7:00

TUESDAY, 9: Symphony Orchestra, 11th floor Rest Room, 6:00
Swimming and Gym. Class, Men, Kittredge School, 6:00

WEDNESDAY, 11: Glee Club, 5:10
Swimming Class, Women, Carroll Club, 5:30

THURSDAY, 11: Swimming and Gym. Class, Men, 6:00

FRIDAY, 12: Bowling, Dwyers Manhattan Alleys, 5:45

SATURDAY, 13: Hike and Camp-Fire Supper

MONDAY, 15: Bridge, Men, Room 275, 6:00
Dance Orchestra, 11th floor Rest Room, 5:15.
Swimming Class, Women, Carroll Club, 7:00

TUESDAY, 16: Symphony Orchestra, 11th floor Rest Room, 6:00
Swimming and Gym. Class, Men, Kittredge School, 6:00

WEDNESDAY, 17: Glee Club, 11th floor Rest Room, 5:10
Swimming Class, Women, Carroll Club, 5:30

THURSDAY, 18: Swimming and Gym. Class, Men, Kittredge School, 6:00

FRIDAY, 19: Bowling, Dwyers Manhattan Alleys, 5:45

SUNDAY, 21: Hike.

MONDAY, 22: Bridge, Men, Room 275, 6:00
Dance Orchestra, 11th floor Rest Room, 5:15.
Swimming Class, Women, Carroll Club, 7:00

TUESDAY, 23: Swimming and Gym. Class, Men, Kittredge School, 6:00
Bell System Bowling Tournament, Men, Dwyers Man. Alleys

WEDNESDAY, 24: Glee Club, 11th floor Rest Room, 5:10
Swimming Class, Women, Carroll Club, 5:30
Camp-Fire Supper

THURSDAY, 25: Swimming and Gym. Class, Men, Kittredge School, 6:00

FRIDAY, 26: Bowling, Women, Dwyers Manhattan Alleys, 5:45
Glee Club Concert and Dance, Hotel Pennsylvania

MONDAY, 29: Dance Orchestra, 11th floor Rest Room, 5:15
Swimming Class, Women, Carroll Club, 7:00

TUESDAY, 30: Swimming and Gym. Class, Men, Kittredge School, 6:00

BELL LABORATORIES RECORD

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President Gifford Addresses the Laboratories

PRESIDENT WALTER S. GIFFORD of the American Telephone and Telegraph Company addressed a group of the men and women responsible for the work of the Laboratories, in our auditorium on April 4. Mr. Gifford was introduced by President Jewett and Vice-President Charlesworth of the Laboratories.

In discussing our work and its relation to the activities of the other associated companies Mr. Gifford first outlined the general policies of the Bell System. He pointed out that although in its general organization and method of carrying on business, the System is in most essential respects similar to other commercial corporations, it differs from them in two important principles. The telephone business is by its nature a practical monopoly and must operate without competition in the usual sense of the word. Its accomplishments are judged not by comparison with others but in relation to what the public thinks may reasonably be expected; and the public is justified in expecting the most telephone service and the best at the least possible cost. In addition to that fact and to complicate the obligations imposed upon us, the Bell System is owned by a very large and widely distributed group of stockholders, the protection of whose investment must at all times be a primary consideration in the management of the System's affairs.

It has always, said Mr. Gifford, been a near-axiom of industry that competition is the life of trade. In other words, constant rivalry for public patronage tends both to improve the product and to increase the efficiency and economy of its production. As this form of competition is lacking in the work of the Bell System, there must be some other incentive which will be equally effective. We like to think that a large part of this incentive is provided by the spirit of service which has so successfully been built up among members of our Bell System. This alone, however, is not enough. A substantial driving force towards more efficient service arises from our organization of headquarters groups of people whose sole duty is to study and devise improve-

ments, and much of this driving force is provided by Bell Telephone Laboratories. If the Bell System is to realize its ideal of providing the best possible telephone service at the least possible cost, and so continue to build up the public good-will so essential to its existence, great responsibility devolves upon the Laboratories of providing new and better means for realizing this ideal.

Such is the primary obligation of the Laboratories. But, as pointed out by Mr. Gifford, aside from this commercial incentive there is another, less practical but no less important; namely, to increase the field of human knowledge. It used to be thought that if a man were to make his fortune in business, he would have to make it at the expense of his fellows. Fortunately at the present time a new conception of commercial enterprise is taking the place of this cold-blooded philosophy. Now when an individual or a corporation strives to obtain greater income, it is possible to mine the riches of nature instead of struggling to take away the wealth of someone else. From this philosophy springs the idea of industrial research which is more and more being applied to every field of business.

In industrial research Bell Telephone Laboratories has long been a pioneer and leader. Until very recent years, particularly in our own branch of research, we have been almost without competition. Now, however, with the rapid spread of the idea of commercial research other organizations are in scientific competition with us and are doing important work. If we are to continue our present leadership and to hold the prestige that we have gained, we must be more and more on the alert to find and exploit promptly new scientific knowledge.

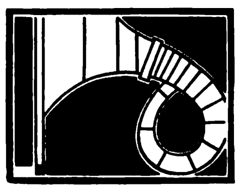
This does not mean, he added, that our rivalry with other organizations should cause us to become jealous of their achievements. It is not wise in science to ignore or belittle the work of others. Rather the true knowledge they have gained should be recognized and accepted as a means of furthering our own accomplishments.

Turning from the Laboratories' peculiar problems to continue his discussion of general System policies, Mr. Gifford pointed out that not only is our research work being faced by new problems and new competition from other industries, but the System's relations to the public are gradually being placed on a new footing. Although in former years our problem was to strive to meet the public's overwhelming demands for telephone service, at present it is also coming to be one of creating public demand for new services, new comforts and conveniences in communication. Here, too, the Laboratories has its own part to play. We cannot academically create designs that we think the public ought to want. Instead we must be alive to the public's preferences; and where such preferences are consistent with efficient service, make every effort to see that they are satisfied.

What's A Good Loud Speaker?

By L. G. BOSTWICK
Research Department

WHAT constitutes a good loud speaker? To answer this question there is needed a more precise method of ascertaining the capabilities of a loud speaker than is provided through a mere listening test. While the ear is, of course, the final judge of the merits of a loud speaker, it is quite unsatisfactory as a means of analysis. One loud speaker may sound better or worse than another with which it is directly compared, but to describe or specify in a definite manner the peculiar characteristics which distinguish one from the other is usually extremely difficult unless the two are widely different. Furthermore, a direct comparison between two devices is necessary, and the magnitude of the difference is always a matter of opinion in comparisons of this sort.



On the other hand, acoustic measurements on loud speakers are complicated by a wide variety of acoustic factors which must be properly considered in order that such measurements be indicative of the capabilities of these loud speakers. Such factors as peculiarities in the distribution of the sound energy by the loud speaker, and sound reflection, absorption and interference effects due to the measuring room enclosure, may cause large variations in the results obtained. When these factors are not taken into consideration, acoustic measurements may give entirely misleading information. The measurements and discussion which follow illustrate the magnitude and character of some of the more important acoustic considerations involved in determining what constitutes a good loud speaker.

The system used in making these measurements is shown diagrammatically in Figure 1. The available power-output of the oscillator is kept constant at all frequencies by means of a vacuum tube voltmeter. With the oscillator connected to a loud speaker, through the transformer, the gain of the amplifier associated with

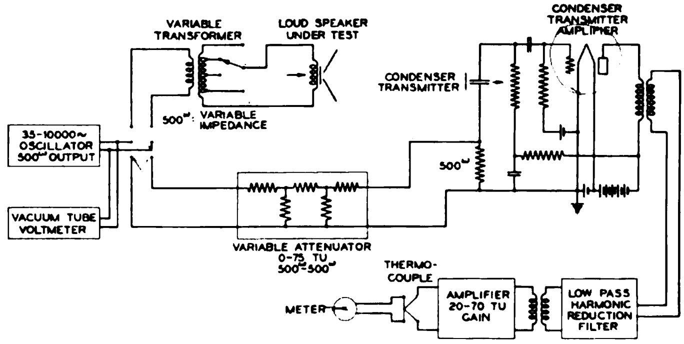


Fig. 1—Schematic circuit of loud-speaker response measuring system

the thermocouple is adjusted at different frequencies until a mid-scale deflection of the meter is obtained as a result of the voltage generated by the condenser transmitter. After each adjustment, the oscillator is switched from the loud speaker to the input terminals of the attenuator, and the attenuator is adjusted to give the same meter deflection. Variations in the attenuator settings with frequency show the variations in the performance of the loud speaker in decibels.*

Performance curves obtained for the same loud speaker by such a procedure may differ widely, due primarily to three causes. These are: variations with frequency in the energy distribution of the sound field of the loud speaker; wave interference at the condenser-transmitter position due to sound reflections from the walls of the measuring room or to a difference in distance from the transmitter to different points on the radiating surface; and variations with frequency in the energy-absorbing power of the measuring room.

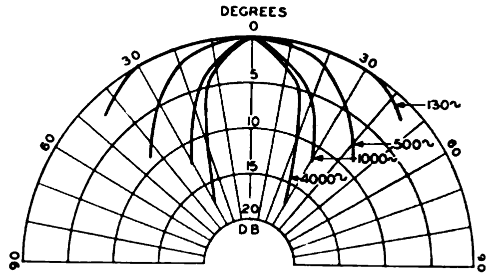


Fig. 3—Polar curves plotted from data of Fig. 2

The magnitude of variations in the sound field distribution can be shown from measurements obtained outdoors in an open field where the effects of any room enclosures are absent. Such measurements appear in Figures 2, 3 and 4, for a 115 cycle cut-off exponential horn with a loud-speaking receiver of the moving coil type. Figure 2 shows response curves obtained when the condenser transmitter is placed twelve feet from the center of the horn mouth and at different angles from the axis. As the transmitter is moved away from the horn axis, the response at the higher frequencies becomes lower, while at low frequencies the change is slight. This is because the angle subtended by the sound field becomes smaller the higher the frequency, and the sound energy is in-

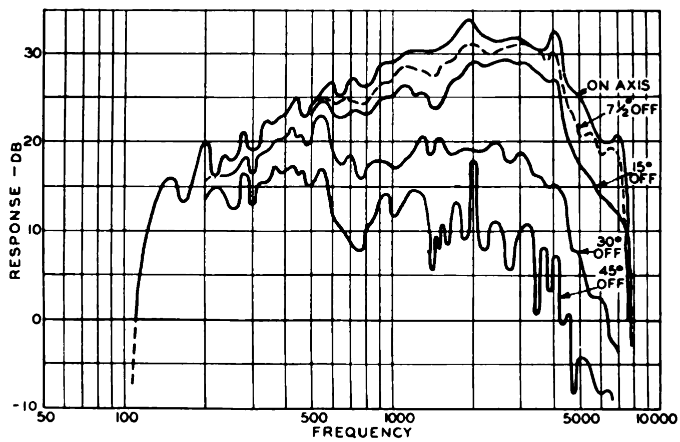


Fig. 2—Response-frequency characteristics of 115-cycle cut-off exponential horn with moving coil receiver. Measured outdoors 12 feet from horn mouth at specified angles to horn axis

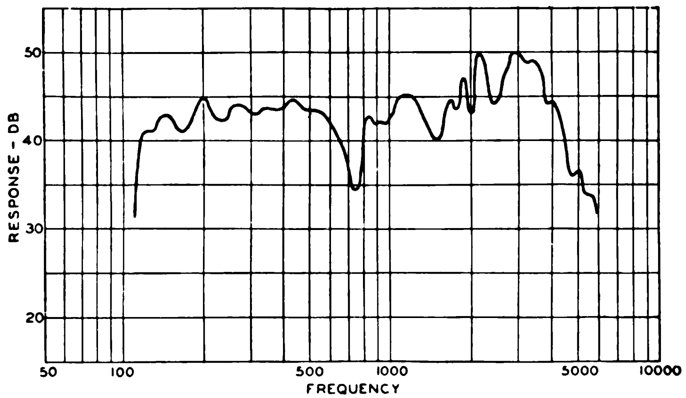
* *This is now the official name of the transmission unit. See* Bell Laboratories Record, *December,* 1928, *page* 137.

creasingly concentrated along the horn axis. Thus a response frequency characteristic of almost any desired trend may be obtained by suitably locating the condenser transmitter. Figure 3 is a polar coordinate curve plotted from the data of Figure 2, showing the sound-field angles for four frequencies.

Figure 4 shows a curve obtained for the same loud speaker, but with the condenser transmitter on the axis only two inches from the mouth. This curve is considerably more irregular than the axis curve of Figure 2. These irregularities can be attributed to interference between sounds reaching the condenser transmitter from different points of the horn mouth. After a distance of about twelve feet has been reached, the sound paths from these points to the condenser transmitter become substantially equal, and therefore, the interference disappears. Thus, the two axial curves in Figures 2 and 4 are quite different.

The effect, on the indoor response measurements, of interference or standing waves due to reflections from the walls of the measuring room is illustrated in Figure 5. These measurements are of a loud speaker with a three-and-one-half-inch diaphragm of the piston type, with the condenser transmitter located about twelve feet away on a line perpendicular to the center of the diaphragm. The loud speaker and transmitter were located equally distant from and on opposite sides of the center of the room, and mid-way between the ceiling and floor. The bounding surfaces of the room were covered with hair felt one-half inch thick. Although an attempt was thus made to reduce the magnitude of the reflections, the curve obtained is very irregular.

One method of compensating for



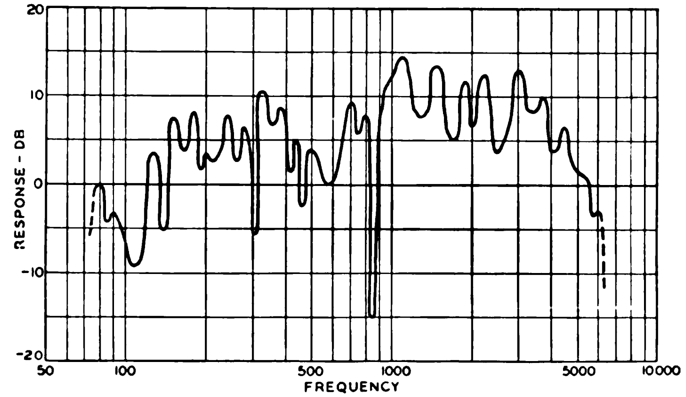


Fig. 4 (above)—Response-frequency characteristic of 115-cycle cut-off exponential horn. Measured outdoors on horn axis two inches from mouth. Fig. 5 (below)—Response-frequency characteristic of 3½-inch piston-diaphragm loud speaker. Measured 12 feet from diaphragm, in highly absorbing room

the effect of standing waves, and of thereby obtaining indoors a curve that is representative of the performance of the loud speaker, is to average the measurements at several positions or within a region rather than at one position. This is accomplished in these Laboratories by a machine pictured in Figure 6. This machine rotates the condenser transmitter in a circle which is nearly six feet in diameter and whose plane is inclined at an angle with the horizontal. Figure 7 shows a curve for the piston-diaphragm loud speaker measured under the same conditions as the curve in Figure 5, but with the rotating condenser transmitter. The center of the circle was located at the same point as the condenser transmitter for Figure 5. A comparison of the solid curve in Figure 7 with the dotted curve, obtained outdoors for the same loud speaker, shows the extent to which rotating the transmitter in this manner obviates the effect of wall reflections.

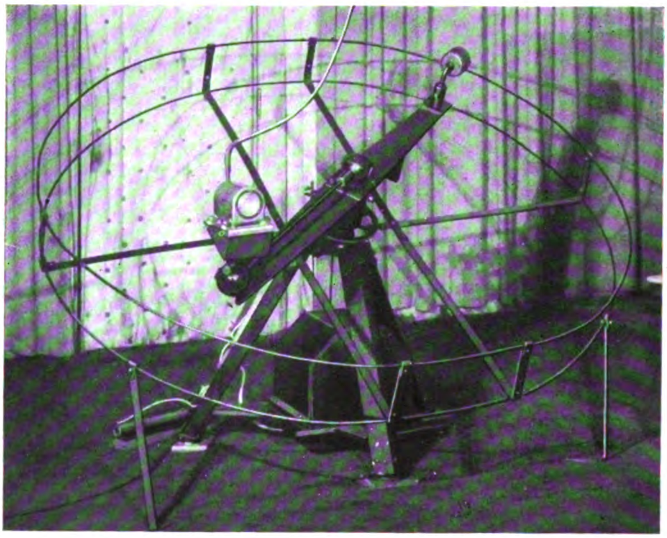
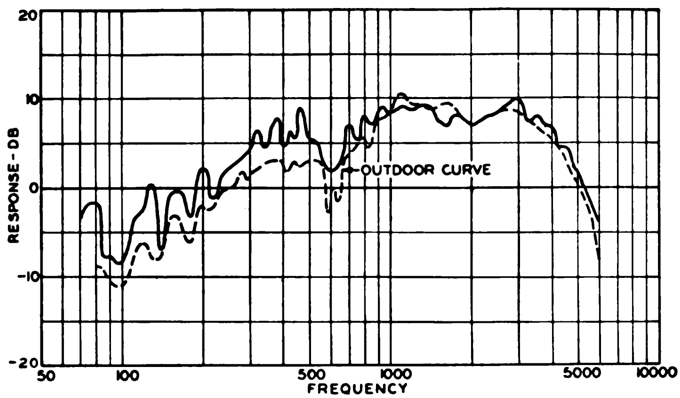


Fig. 6—Machine for rotating condenser-transmitter to make indoor loud-speaker measurements

The uniformly greater response at low frequencies of the indoor curve in Figure 7 can be attributed to the fact that the sound absorbing ability of the measuring room varies with frequency. Indoors the energy reaching the condenser-transmitter position directly from the loud speaker is supplemented by energy reflected to the same position from the walls of the measuring room. Variations with frequency in the reflecting or absorbing ability of the walls of the room will, therefore, cause variations in the magnitude of the response measurements. From the difference between the two curves in Figure 7 it is possible to calculate the ratio of the outdoor to indoor energy densities at different frequencies at the transmitter position and to obtain the solid curve shown in Figure 8. The dotted curve is an average curve showing the trend. A comparison of this dotted curve, with the dot-dash curve of the absorbing ability of one-half inch of hair felt, shows an interesting correlation in the trends of the two curves. The difference in magnitude of the two curves can be accounted for by the fact that the sound passing through the transmitter position probably undergoes several reflections before returning to this position again.

From the above illustrations it is obviously quite impossible to deter-

mine from acoustic measurements whether or not a loud speaker is "good," unless the curves expressing the measurements are qualified by statements regarding the measuring conditions. Especially must information be given as to the position of the condenser transmitter relative to the loud speaker, the method of measurement (whether pressures are measured at one position or averaged within a region), and the size and nature of the medium. In general, response measurements, to be most indicative of the capabilities of a loud speaker, should be made with the condenser transmitter at a distance from the loud speaker commensurate with or equivalent to the most likely listening distance of an observer. In addition, determining which of two loud-speaker response curves is the better requires an interpretation of the auditory significance of the magnitude and position in the frequency spectrum of departures in the curves from a straight horizontal line. Such an interpretation involves physiological considerations. Although complicated by such a wide variety of factors, the response-frequency characteristic has been found the most significant single criterion upon which to base a judgment of the merits of a loud speaker.



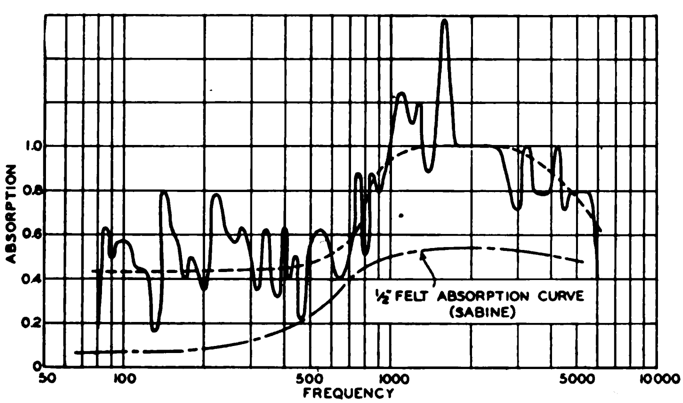


Fig. 7 (*above*)—*Response-frequency characteristic of* 3½-*inch piston-diaphragm loud speaker. Measured in highly absorbing room and averaged in small region* 12 *feet from diaphragm. Fig.* 8 (*below*)—*Absorption-frequency characteristic of felt-lined room with respect to a region relatively near its center and the sound source. Calculated from data of Figure* 7

Extending the Usefulness of the Oscillograph in Circuit Testing

By I. H. GERKS
Systems Development Department

ORDINARY oscillographs of the electromagnetic type are not sufficiently sensitive to permit the proper recording of many electrical phenomena occurring in telephone circuits. To correct this deficiency a specially designed amplifier has been built to supplement the oscillograph when it is necessary to measure very small currents or voltages. With the assistance of this auxiliary amplifier it is possible to record, measure, and study the most minute currents and voltages that are likely to be of interest in telephone circuit engineering.

With the ordinary oscillograph operating under average conditions, approximately 0.001 ampere must be passed through the vibrator coil to give a deflection of one millimeter on the film. This means that a deflection of one centimeter, which is about the least that will give a readable oscillogram, requires a current change of approximately 0.010 ampere through the vibrator. In many circuit problems, current changes of a much smaller value must be studied. With a "B" type relay, for example, operating on a current of the order of 0.001 ampere, it is impossible with the ordinary oscillograph to determine the exact instant at which the current in the winding starts to build up, particularly if the time constant of the circuit (ratio of inductance to resistance) is large. Inability to determine this point accurately makes it impossible to measure operating times satisfactorily. Busy-test clicks in the operator's headset produced by voltages of only a few hundredths of a volt are also difficult to record and measure with an ordinary oscillograph.

Besides the difficulty with very small currents and voltages, conditions are frequently encountered where the current drawn through the vibrator is sufficiently large to alter the characteristics of the circuit to a considerable extent. In such cases the voltage recorded by the oscillograph would be lower than the true voltage because of the shunting action of the vibrator. Also, there are many cases in which variations of a small magnitude in a comparatively large steady current must be measured. To prevent the oscillograph vibrator from being damaged by the large steady current, a low-resistance shunt path across the vibrator must be provided. This shunt makes the oscillograph insensitive to such an extent that the small variations which are to be recorded may be entirely lost.

It was to meet these special conditions that a special two or three stage resistance-coupled amplifier was developed. It consists of three vacuum tubes with the associated coupling and control circuits and the necessary bat-

teries, all mounted in a "tea wagon" for portability. From a circuit standpoint, it is very similar to the familiar resistance-condenser-coupled audio amplifier used in radio receiving sets, but a battery is used in place of the condenser. Its chief advantage is its amplifier, the current to be measured must be passed through a resistance, and the voltage drop across this resistance impressed on the grid circuit of the first vacuum tube. The sensitivity of the three-stage amplifier is such that a variation of approxi-

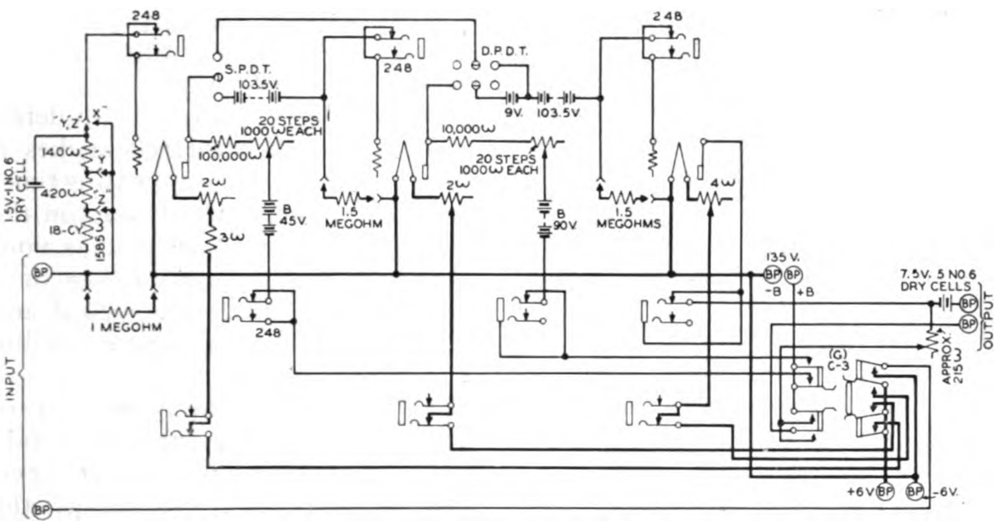


Fig. 1—The new amplifier for the oscillographs may be changed from three stages to two stages by operating the switches designated S. P. D. T. and D. P. D. T.

ability to amplify direct as well as alternating currents. By means of a pair of switches it can be changed from a three-stage to a two-stage amplifier when great sensitivity is not required.

It will be recalled that for a given change in the voltage impressed on the grid of a vacuum tube, there is a corresponding change in the plate current. Consequently, when the instrument is to be used as a current mately 0.01 volt on the grid of the first tube results in an oscillographic deflection of one millimeter. A variation of a tenth of a volt will, therefore, give a satisfactorily readable oscillogram. To obtain a voltage drop of a tenth of a volt when the input current is 0.001 ampere, an input resistance of one hundred ohms must be used. The insertion of a resistance of this magnitude into the circuit under test is generally permissible, since it will as a rule form but a small part of the total impedance of the circuit in which such small currents are encountered. With an input resistance of this value a current amplification of approximately ten is obtained, and other amplifications are readily obtained by

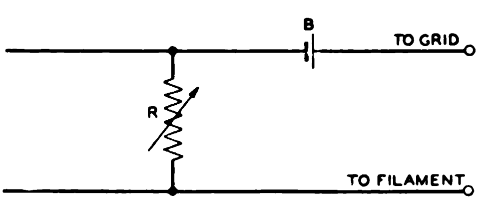


Fig. 2—An adjustable resistance is used as a shunt when small ripples in a large direct current are to be measured



Fig. 3—The raised cover of the amplifier discloses the copper lining that serves as a shield

changing, at will, the value of this input resistance.

When the instrument is to be used for measuring small voltage variations, the input terminals of the amplifier are connected directly across the circuit being tested. Since the grid-filament resistance of a vacuum tube, operated with a negative bias on the grid, is very large, the amplifier acts as a very high impedance voltmeter, leaving the characteristics of the circuit under test practically unchanged. When the total voltage variation above or below ground potential exceeds a tenth of a volt, it is necessary to divide the voltage by means of a high-resistance potentiometer, to avoid overloading the amplifier and introducing serious distortion.

When the instrument is used in a circuit where a small alternating current is superimposed on a relatively large direct current, an auxiliary circuit, such as that shown in Figure 2, may be used to balance out the direct current and permit proper amplification of the small variations which are to be measured. The direct current flowing through the resistance R causes a voltage drop exactly equal and opposite to the voltage of the battery B. Any variations in the current, however, upset this condition of balance and introduce a corresponding voltage input to the amplifier. The resistance R, of course, must be sufficiently low to make no appreciable change in the total impedance of the circuit under test.

The three-stage amplifier was built

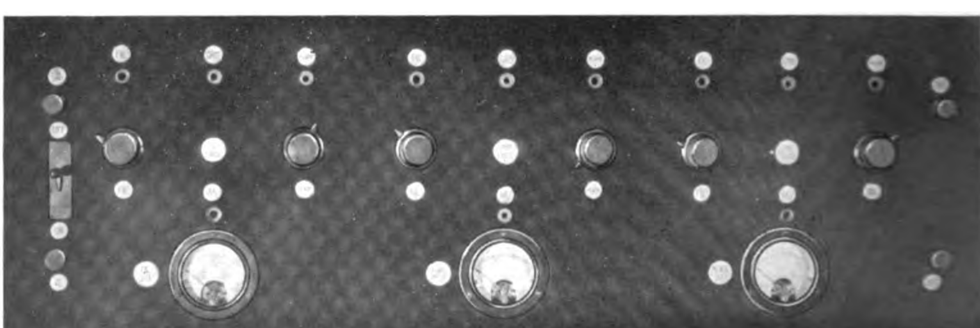


Fig. 4—To the operator looking down from above, the amplifier presents the appearance shown here

primarily to extend the range of the oscillograph in the manners just described, and for this purpose it has proved very satisfactory. Since circuit studies involve frequencies varying from zero to about 3000 cycles per second, it is desirable that all frequencies within this range be amplified equally. This requirement has been met by the new amplifier which has a frequency-amplification curve that is practically flat within this range; in fact, the dropping off in amplification does not become appreciable until 10,000 cycles is reached.

Some of the things which can be done with the oscillograph in conjunction with the amplifier that would otherwise be impossible are illustrated by the oscillograms of Figures 5 and 6. Figure 5 shows oscillograms of a few of the standard tones obtained both with and without the amplifier, the first being "audible ringing," the second, "busy back," and the third, "dial tone." It is apparent that no satisfactory study of the wave shape of these tones could be made using only the unamplified oscillograms.

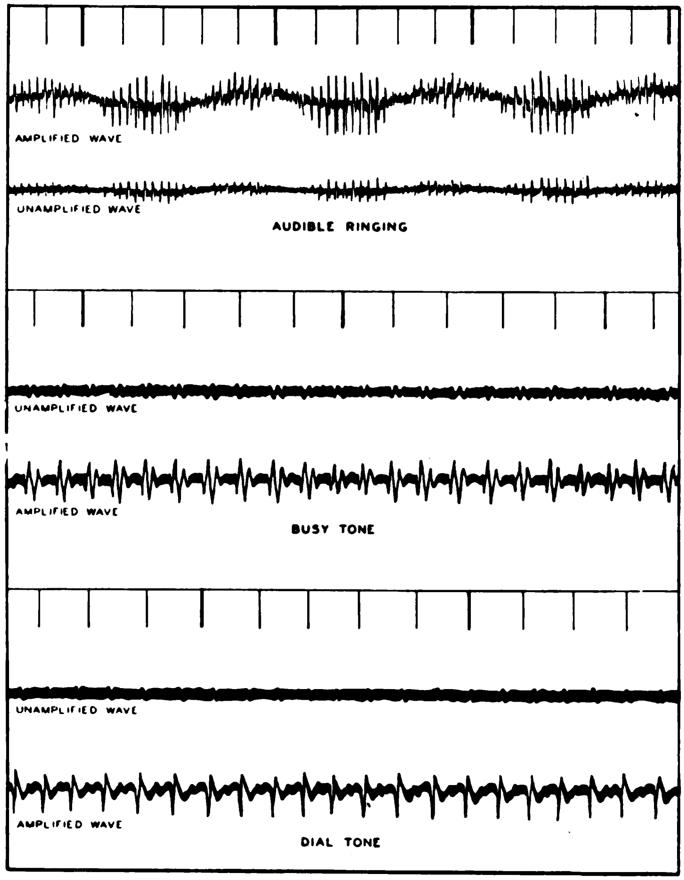
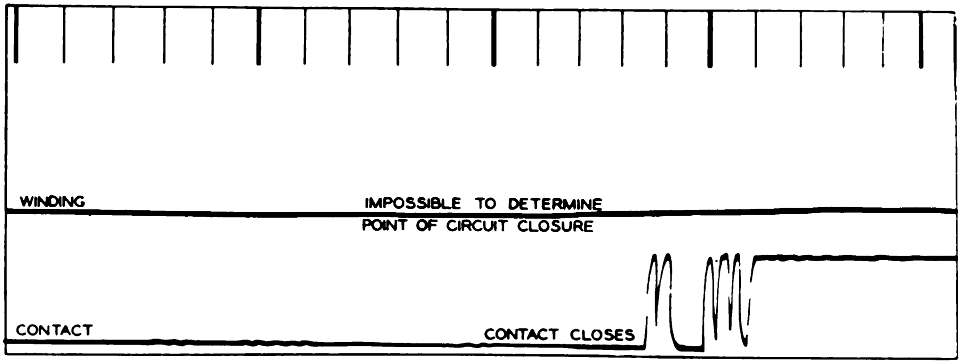


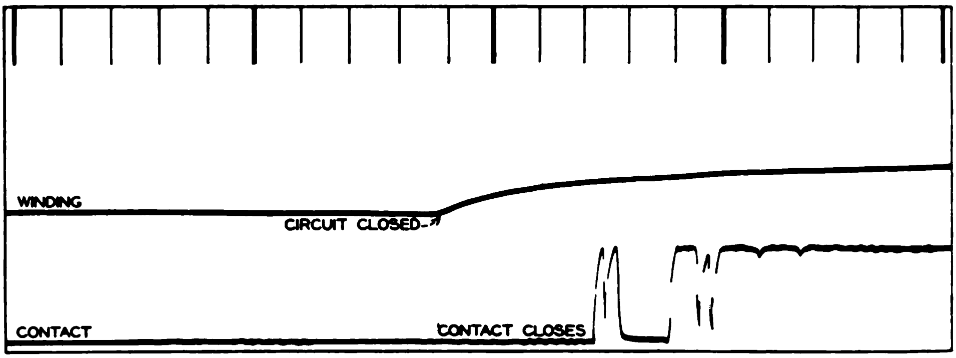
Fig. 5—Oscillograms of three ordinary tones are shown here both with and without the use of the amplifier

Another, and perhaps the most important, use for the amplifier in the circuit laboratory is in measuring the operating and releasing times of relays where the current is too low to produce a readable deflection. Consider, for instance, a B-24 relay which operates on 0.0008 amperes. Figure 6-A shows the build-up of the current in the winding as it appears with the oscillograph adjusted to its maximum sensitivity but without the amplifier. Figure 6-B shows the same condition making use of the amplifier. From the former it is impossible to tell where the winding current starts to build up but the point is very evident when the amplifier is used.

If the amplifier is calibrated on



OPERATING TIME OF B-24 RELAY - NO AMPLIFICATION



OPERATING TIME OF B-24 RELAY - CURRENT THRU WINDING AMPLIFIED

Figs. 6-A and 6-B—Amplification is necessary to show the building up of current in some types of relays

direct current, it can be used in conjunction with the oscillograph to measure very small transient currents and voltages. Also, if an alternating current milliameter is inserted in the output circuit in place of the oscillograph, the device becomes a very sensitive alternating current meter and supplements direct reading instruments of this type, which are inherently insensitive. Although only a few of the more important uses of the amplifier have been touched upon here, the extent of its possibilities has probably been indicated. Its usefulness will, no doubt, be further extended in the future as new circuit problems arise demanding distortionless amplification over a very wide range of frequencies.

Patents as a Means of Both Protection and Publication

By H. A. BURGESS
Patent Department

A PATENT is a governmental grant of certain rights in an invention. The nature of the rights is fixed by law. The nature of the invention and the scope of the subject matter on which the rights are granted are defined in the patent. These rights constitute the patentee's protection, in that they enable him to prevent the unauthorized use of the invention by others. The patent is also a public document addressed to "all whom it may concern," and thus a publication of the invention disclosed in it. The description of the invention is an essential part of the patent and has as its main requirement that it be sufficiently complete and clear to enable one familiar with the related art to practice the invention.

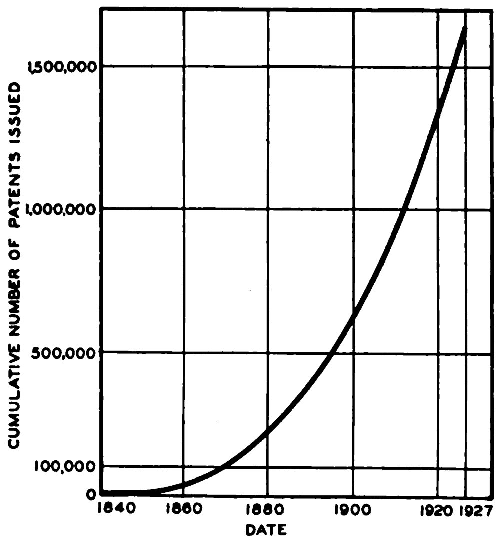
The rights granted to a patentee are an absolute monopoly for a limited time — in this country seventeen years. The question which, perhaps, first occurs to the mind of anyone not intimately acquainted with the patent system is, "Why should the government, that is, society, be interested in giving to anyone a monopoly right in an invention?"

To answer this question, suppose that a new machine is invented which reduces the cost of production of an article by one-half. This new machine is valuable not so much on account of what it is as on account of what it is able to do. It may be made of steel, and its intrinsic worth as so many pounds of steel may be very small. It is not the material of the machine which gives it value, but its characteristic and useful action. Whoever copies this machine and puts the copy to use obtains the same benefits as come from the use of the original machine. The copy, therefore, takes on value because it can perform a valuable function. Is it sound economic policy for society to recognize a property right in the characteristic pattern, plan or idea as distinguished from the property right in the machine as so much material? Since the idea is what imparts especial value to the material, society has answered "yes" to this question and has set up the patent laws to protect property rights in inventive ideas.

Knowledge of the plan of this machine can be spread very easily. A description or a sketch is all that may be required to acquaint the whole industry with the new mechanism. On the other hand, the machine may have been developed at very considerable cost of time and money. An adequate return on the investment represented by the development work can only be had by guarding the machine against being copied. If the party who bore the cost of new developments could not derive adequate returns from them, sound economics would dictate

that all parties become copiers rather than originators. The result would be a condition not very productive of improvement through expensive experiment and development studies.

The answer to the question why society is willing to grant a monopoly



Curve showing the number of patents which have been issued in the United States since 1840. *From* 1790, *when the first U. S. patent appeared, to* 1840 *about* 10,000 *patents were issued*

right to an inventor in his invention is found in the general proposition that society is interested in progress in the industrial arts, and that such progress is prospered as the contributors to it are prospered. It is to the interest of society, therefore, to reward the real contributor or originator of any new practical technical advance. This is what the patent system aims to do, by giving the patentee a monopoly right in the invention. Exclusive control of an invention by keeping it secret is precarious; if the invention is an article of commerce, secrecy is impossible. The patent relieves the patentee entirely of secrecy measures and allows him to make, use and sell his invention openly and to any extent while still giving him protection against unauthorized use of the invention by others. Society gains the benefits which come from introduction of the invention into commerce. Another important benefit to society is that after the expiration of the patent the public comes into full possession of the invention and may use it without obligation to the inventor.

An important characteristic of a patent is the even balance which it strikes between what the inventor gives and what he gets in return. If an invention which seemed important turns out later to be valueless, the monopoly right in the invention is equally valueless, and neither the inventor nor society has bestowed any benefit on the other. The monopoly right to a valuable invention, however, is valuable, and puts the inventor in the way of gaining a reward for his efforts. In a sense the inventor writes his own patent grant, and the grant proves valuable or not as he contributes much or little to the fund of technical knowledge.

The picture presented by the foregoing illustration is not complete without including consideration of the many inventions which are made but which do not find immediate commercial application. Such are, for example, by-product inventions, resulting directly from study or experimentation, but not meeting the requirements of the particular problem in hand. Such also is the output of the inventor who is not himself interested in making or using the products of his inventive skill. Many of these inventions may be valuable in the

hands of others, and it is, therefore, in the interest of society to provide an inducement for bringing these inventions to light and encouraging their adoption and use. This the patent system accomplishes by giving these inventive ideas the legal status of property in which rights may be transferred or sold.

We hear it commonly stated that the patent laws offer an inducement to invention. While this is undoubtedly true, it does not represent the whole truth. The patent laws are also an inducement to the inventor to make his inventions known. An inventor may make ever so many important inventions, but he gains no recognition by the patent laws until he shows an intention to make them clearly known and ultimately freely available to the public. This is demonstrated continually in cases of litigation between two rival claimants for the same invention. The inventor really the later in point of time may be held to be prior in law, if his opponent has stood by and done nothing while he was diligently perfecting the invention and making it available to the public. Society has manifested no interest in inventions that have been made and filed away in private archives or secretly preserved for possible future use. These inventions might as well not have been made, so far as concerns their effect upon the public good. Society is interested in having inventions brought forward and given public disclosure. Only by so doing does the inventor place himself in position to claim the protection which society stands ready to extend for new and useful inventions.

The importance of the patent as a publication is two-fold. The patent must provide sufficient data to enable anyone conversant with the related art to practice the invention when the patent expires. The publication also has the immediate effect of acquainting other workers with the advance step represented by the invention, and this acquaintance not infrequently suggests to others a further improvement. Patents thus become an effective agency in the dissemination of technical information. Since their chief concern is the disclosure of what the inventor regards as his personal contribution, they afford a means of registering systematically each forward step in the development of an art. Once the patent application has been filed, moreover, the inventor's record date has been established and he may without prejudice to his rights publish the invention in any way he may choose. The patent system thus permits the prompt publication of inventions in technical journals without loss of protection to the inventor.

It is interesting to consider the importance of a patent system to industrial research organizations such as these Laboratories. There are many such organized groups in this country studying ways and means of promoting the existing industrial arts, and even creating new lines of endeavor. Here we see the patent system operating in two important respects. It gives to the products of the inventive efforts of the group the status of a property recognized by law. The exclusive property in the inventions so made represents value and constitutes part of the economic justification for the costs of the research. Furthermore, the patent system enables the groups to work much more openly than they could if the

only protection for the new ideas came through keeping them secret. Publication of results is perfectly consistent with retention of full rights in the property of the new ideas. This fact enables the different groups to be informed of one another's accomplishments and creates an atmosphere of stimulation, cooperation and healthy rivalry. It also enables due credit to be given to the originators of new ideas.

The broad policy of the American patent system was concisely stated by the Supreme Court of the United States in an opinion handed down about seventy years ago.* The Court said in part:

"It is undeniably true, that the limited and temporary monopoly granted to inventors was never designed for their exclusive profit or advantage; the benefit to the public or community at large was another and doubtless the primary object in granting and securing that monopoly. This was at once the equivalent given by the public for benefits bestowed by the genius and meditations and skill of individuals, and incentive to further efforts for the same important objects."

At the time of that opinion the telegraph was in its infancy. The telephone was as yet unknown. The next half century was destined to see not only the telephone but the radio operating on a commercial basis. In fact, all communication by electrical means up to and including radio was developed within the span of a single lifetime. Such an acceleration in the creation of new ideas could have come about only through the dissemination of technical knowledge. In this, as well as in furnishing a stimulus to the investigator by rewarding his successes, the patent system has played an important part.

* *Kendall vs. Winsor*—62 *U. S.* 165.

The National Academy of Sciences, meeting in Washington, has elected to membership Clinton Joseph Davisson of our technical staff, for his researches in electronic physics. Membership in the Academy, which was founded at the instigation of President Lincoln, is considered as the highest honor which can be conferred on an American scientist. Among members who are physicists may be noted Michelson, Millikan, Pupin, Wood, Karl Compton, Lyman and Arthur Compton. Other Bell System members are General Carty and Doctor Jewett, elected as outstanding members of the engineering profession.

The Pulse Corrector

By R. C. PAINE
Systems Development Department

As is well known, the voice currents of telephone conversations, diminishing as they pass along from transmitter to receiver, are when necessary magnified at intermediate points of long-distance circuits by repeaters. Not so well known, perhaps, is a comparable need in the step-by-step dial system for reinforcing the trains of current impulses by which the switches are operated. In cities having two or more step-by-step operating centers each inter-center dial trunk has at its originating end a relay which passes on the impulses incoming from the calling subscriber's dial. The pulses are however, distorted by inductances and capacities effective in the trunks over which they pass. Trunks long enough for the distortions to be objectionable are therefore fitted at the terminating end with a correcting circuit which supplies to the switches pulses the same as those produced by the subscribers' dials.

Dial pulses are made up of two periods — one transmitted when the circuit through the dial is open, and the other when it is closed. A characteristic of the pulses which must not vary beyond rather wide limits is the relative length of these periods or, as it is more commonly expressed, the ratio of an open period to an entire impulse. That ratio, generally termed the "per cent break," can by the construction and adjustment of the dials be given any desired value at the calling subscriber's station. Between that station and the dial office however there are effective capacities and the inductances in addition to resistances; on calls in multicenter areas there are additional capacities and inductances as well as resistances, before the terminating office is reached. Furthermore, mechanical movements of certain parts of the apparatus affect the pulses allowed to reach the switches. The per cent break is therefore not that given by the dial, but is a modification depending on characteristics of the path over which the pulses have passed. Ordinarily no difficulty is experienced, but when the distance between the originating and terminating offices is beyond the normal dialing range, the selectors and connector may receive impulses whose per cent break is high enough to prevent correct operation.

The reason for that situation is the cycle of events which takes place at the arrival of the pulse group controlling a particular switch movement. The pulses do not go directly to the magnets which move the contact arm, but to a pulsing relay from which there are sent out new, stronger pulses whose per cent break depends upon that of the pulses received. In its operation the armature of this relay alternately makes contact on two points — on one during the closed periods of the pulses, and on the other during the open periods. The intermittent current flowing by turns through the circuit branches con-

nected to the two contact points holds the switching circuit closed in two places, by means of slow-release relays. When the per cent break is either too short or too long the armature holds too long at one contact and remains too long away from the other. Current through one of these contacts is thus interrupted for such periods that the associated slow-release relay restores to normal, preventing correct completion of the call. Failure may also result unless the pulses transmitted to the stepping magnets are sufficiently long to insure a step for each pulse.

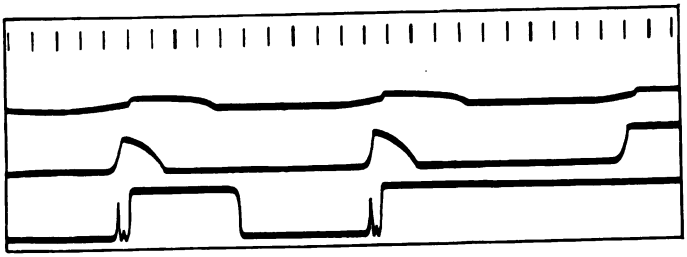


Fig. 1—Oscillogram of the start of a train of pulses incoming from a long trunk. In this figure, and in Fig. 2, the top curve represents the pulses as received from the trunk; middle, those issued by the pulsing relay A; bottom the pulses transmitted to the subsequent switch by the pulse corrector. Each division on the scale represents 0.01 *second. These oscillograms read from right to left*

Each incoming trunk at a step-by-step office is permanently associated with a selector which operates in accordance with the first digit of each group of pulses received. It would be possible to give this switch an individual adjustment to make it operate reliably on pulses from its particular trunk, even though this trunk were too long for satisfactory dialing otherwise. Such adjustment would however be insufficient. Pulses for the subsequent digits, passing through the contacts of the first switch, control the succeeding switches. Since these later switches are accessible to any calls completed in the office, coming in from trunks of any length, they cannot be adjusted for pulses from a particular group of trunks.

One solution of the difficulty would be to divide these subsequent switches, segregating a group through which the only calls passing would be those from the longest trunks, and adjusting those switches correspondingly. Although workable, such a division of the switches into two or more separate groups is inefficient from the standpoint of traffic capacity. As is well known, each switch in a small group cannot handle as many calls as if it were in a large group, if in both cases the same percentage of calls meet an "all switches busy" condition. Maintenance of any specific standard of service with the switches

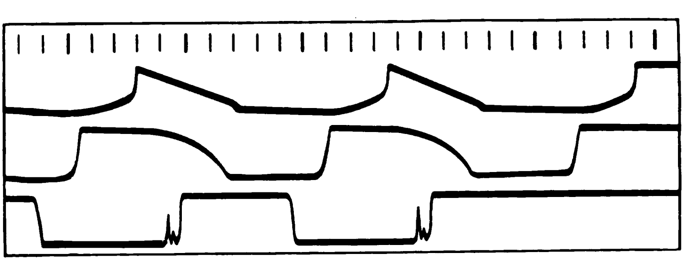


Fig. 2—Oscillogram of pulses incoming from a short trunk. Such pulses do not need correction, but were corrected to permit comparison with Fig. 1

divided into sub-groups would therefore necessitate installation of considerably more switches than would otherwise be needed.

To avoid any such arrangement, and to prevent dependance on extremely close adjustments for correct operation, there has been developed a pulse corrector for use on long trunks. This piece of apparatus replaces the incoming pulses, regardless of their per cent break, by new impulses whose open and closed periods have predetermined values. The occasion for correction, and the means for its accomplishment, may be compared to the situation in telegraphy, where the signals are distorted in their passage over land circuits or submarine cables. For many years regenerative repeaters, as they are known, have been used to re-transmit telegraph pulses incoming to them, after strengthening them and restoring them to their original wave form. Somewhat similar principles are employed in the pulse corrector in bringing to the desired wave shape the strengthened pulses which are sent out.

The mechanism for accomplishing correction consists mainly of a group of condensers and relays, of which a simplification is shown in Figure 3. More units are involved, but the essentials of operation are illustrated by the condenser and five relays shown. The group goes through its operating cycle once for each pulse received, and sends out to the succeeding switches a new pulse whose open period is governed by the time of operation of one of the relays and the release time of another. The total length of the new pulse is the same as that of the old, namely, the length originally given by the dial; although distorted by the intervening line, the dial pulses are not changed in overall length. Open and closed periods are therefore definitely fixed —the former by the pulse corrector, and the latter jointly by the pulse corrector and the subscriber's dial.

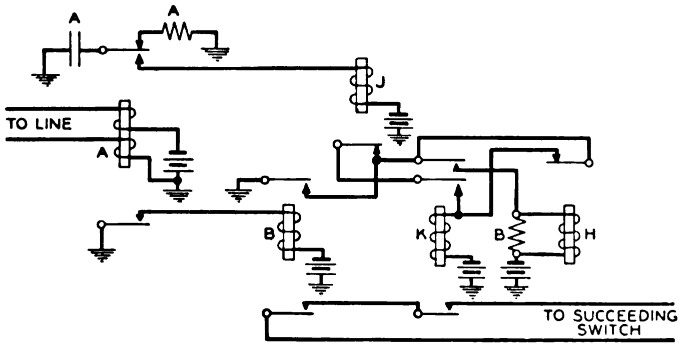


Fig. 3—Simplified diagram of the pulse corrector. Relay K, releasing breaks the circuit to the succeeding switch, to start each outgoing pulse. Thereupon slow-release relay H releases and relay K, reoperates to close the circuit and end the open period of the new pulse

The stimulus which starts the cycle of operations is a momentary condition—charging of the condenser shown, at the beginning of the closed period of each incoming pulse. The pulses received may therefore be distorted to a large degree without preventing the sending out of new pulses with the predetermined open and closed periods. The oscillograms show two groups of pulses as received from long and short incoming trunks, as passed on by the pulsing relay, and as made ready for switch operations by the pulse corrector. In one group

the per cent break is about twice that of the other, but the pulses sent out by the pulse corrector are the same in both cases. It is interesting to note from the oscillograms that the corrected pulses are delayed almost a complete cycle from those received. That delay, about a tenth of a second, arises from the fact that the open period of a corrected pulse is not sent out until the pulsing relay has closed for the next incoming pulse.

To insure satisfactory dialing, interoffice trunks in the step-by-step system have usually been limited to a maximum resistance of 1200 ohms. When 19-gauge cable is used, that figure is reached on trunks approximately thirteen and a half miles long. In most cases that distance is adequate; it is mainly in the smaller cities, where the farthest operating centers are seldom more than a few miles apart, that the step-by-step system is advantageous. Local conditions have however brought about its adoption in certain large communities, and it is used in some cities with a population well over a million. In addition, it is commonly used in cities a number of miles apart but having a rather large volume of intercity calls. It is for these cases, and for others similar, that pulse correctors are valuable. They more than double the maximum trunk resistance at which satisfactory dialing can be maintained without special adjustment of the step-by-step switches. Not only so, but they can be installed at intervals in a connection to increase the pulsing range as much as necessary; this is done on certain connections handled through step-by-step tandem offices. Thus there is an economical and reliable means for transmitting dial pulses over circuits of any length that, being within the limits set by the requirements of supervision and transmission, may be seriously considered for through step-by-step calls.

Nearly $82,000,000 *is to be spent this year on new Long Lines facilities, an increase of* 67 *per cent over the* 1928 *expenditure. About half this sum will be spent on extending the long-distance cable system by* 2500 *miles. In addition the Associated Companies will add a thousand miles of similar cables.*

The Long Lines construction program includes supplying a million loading coils and about 24,000 *telephone repeaters to be used in connection with new and existing cable lines, the stringing of* 74,000 *miles of new aerial wire through less populated areas, and new pole lines, calling for an expenditure of* $10,000,000; *and the installation of fifty-eight carrier current telephone systems and twenty-four carrier current telegraph systems. To supplement the present telephone facilities to Europe, three additional short wave transoceanic telephone systems will be constructed, and likewise an additional short wave system will be provided for telephone service with South America via Buenos Aires.*

Prize Winning

PHOTOGRAPHS

of the Club Contest

1929

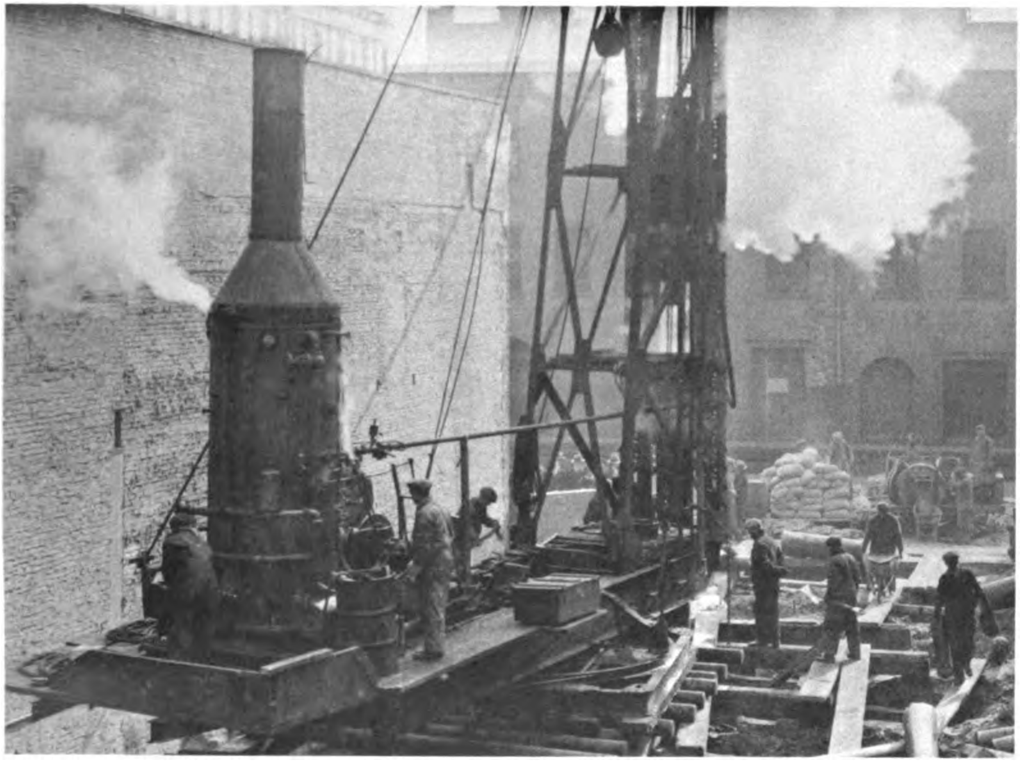
BELL LABORATORIES CLUB



First prize, landscape class: E. Alenius



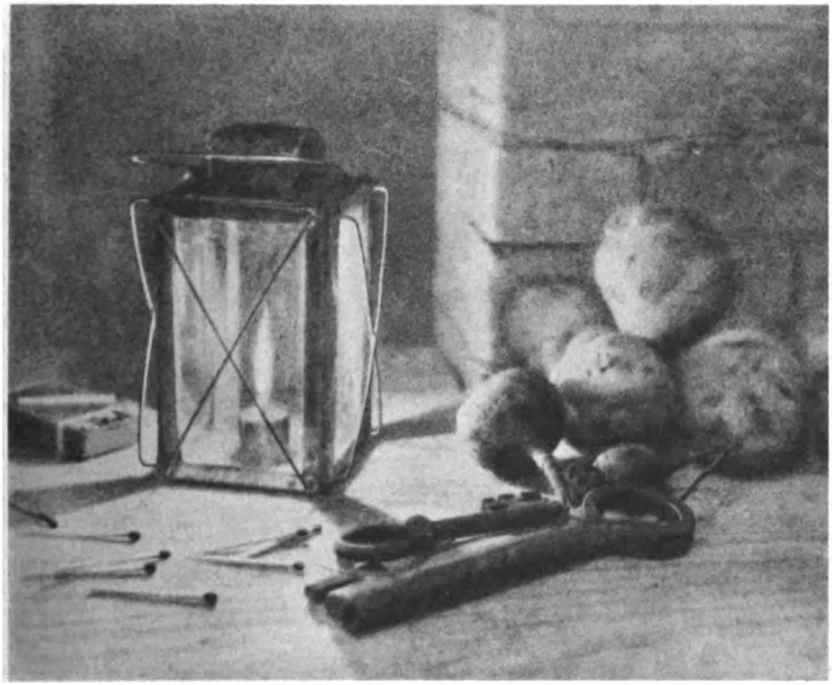
Second prize, landscape class: G. R. Lum



Third prize, landscape class: J. Popino



First prize, portrait class: C. G. Scofield



First prize, still-life class: E. Alenius



Second prize, portrait class: G. Scheeler



Third prize, portrait class: C. G. Scofield



Second prize, still-life class: C. G. Scofield



Third prize, still-life class: E. Alenius

Photographic Data

First Landscape: Ica camera; Carl Zeiss f 4.5 lens; exposure 1/25 second in sunlight at f 16; Eastman roll film; Bromoil paper and printing; clouds, path, and bushes taken from other negatives made with the same camera.

Second Landscape: Contessa Nettel camera; f 6.3 Protar lens; exposure 1/25 second at f 9; Eastman film pack; enlarged on P. M. C. No. 9 Bromide paper.

Third Landscape: 8 x 10 view camera; Goertz Dagor lens, 14 foot focal length; Eastman commercial Ortho film; exposure 1/50 second at f 16; part sunlight, mostly heavy shadow; enlarged on Gaevart Bromide rough semi-matte paper.

First Portrait: Century studio camera; Vitax f 3.8 lens; exposure 2 seconds at f 6.3 with about 6000 watts diffused Mazda light about 15 feet away; negative made on 4 x 5 inch Eastman Par Speed film and developed in Pyro; enlarged print made on Defender Velour Black rough buff paper, developed in metol-hydrochinon and varnished.

Second Portrait: 3¼ x 4¼ Graflex camera; f 4.5 lens; exposure 1/40 second in sunlight; commercial Orthonon film; enlarged on Novabrom rough buff paper.

Third Portrait: Same conditions as first portrait.

First Still-Life: Ica camera; Carl Zeiss f 4.5 lens; exposure 45 seconds at f 11; Eastman cut film; Bromoil paper and printing.

Second Still-Life: 3¼ x 4¼ Graflex camera; f 4.5 Eastman lens; Eastman commercial film; exposure 1½ minutes at f 16 with 150 watt bulb in reading lamp on table; printed on Velour Black semi-matte white paper.

Third Still-life: Ica camera; Carl Zeiss f 4.5 lens; cut film; exposure about 30 seconds at f 11; 100 watt lamp about 5 feet from subject; Bromide paper and printing.

Routine Tests in a Panel Office

By L. M. ALLEN
Systems Development Department

FAULTS, occurring with telephone equipment, may be divided into two classes: those that disclose themselves to a subscriber or a Telephone Company employee, and those that are discovered by tests. Even though a definite report of the trouble is made, as happens with faults of the first class, it is frequently necessary to make tests to determine the direct cause of the trouble because the fault may not exist in a piece of apparatus directly connected with the subscriber's line or trunk that has been reported, but in some other unit required to complete the connection.

To insure, therefore, that telephone switching mechanisms and circuits are functioning properly, periodic tests are made on the principal units of the system. These are called routine tests. The name means that the tests are made not because of a reported failure, or because of any indication of trouble, but rather to locate equipment that is approaching the failure point. The effort is made to seek out and correct faulty equipment before the defects have become serious enough to give trouble under service conditions. Such faults as broken wires would not, of course, fall in this class, but it can readily be seen that a relay whose adjustment is gradually weakening can, by having a severe test imposed on it, be detected and have its adjustment corrected before it has weakened sufficiently to cause a service failure.

Year by year better and more reliable apparatus and circuits are used, but a telephone system is so extensive and complicated that it is not commercially possible to develop one that could continue permanently free from sources of trouble. Foreign material between contacts so that electrical paths are not properly closed, wear of mechanical parts, and innumerable other things may occur to cause trouble. Each, as it develops, must be located and corrected to keep the system operating properly.

With the manual system, one or more operators are required to complete each connection, and in the event of trouble the operator can record the line and trunk involved so that the trouble may be located. With the dial systems, on the other hand, there is no human supervision on the connections established. Should the calling subscriber experience trouble when establishing a connection and make a second call which is successfully completed, he will very likely fail to report the trouble. Even though it were reported, considerable effort would be required in most cases to determine the source because in establishing a connection from one telephone to another it is highly improbable, except during periods of extremely light load, that the same train of switches would be used on any two of a number of successive calls. To maintain the high standard

of operation required by the Bell System, troubles must be located before they interfere with service, by frequent tests made according to a systematic routine.

Some of the testing circuits are of the automatic type, performing their testing operations without other than supervisory assistance from an attendant. Such an automatic circuit used to test incoming selectors is shown in Figure 1. Generally, testing circuits of the automatic type are permanently located as close as possible to the circuits that they are designed to test.



Fig. 1—An attendant is here shown operating one of the control keys of an automatic incoming-selector test frame

The only action necessary on the part of the attendant to place in operation an automatic test frame such as that for incoming selectors is the manipulation of a few keys. When these have been operated the testing circuit associates itself with a district or office selector, temporarily removes it from service, and controls its movements so as to connect the testing circuit with the various incoming selectors that are to be checked. It is, of course, necessary to use a number of district or office selectors in sequence in order to obtain access to all incoming selectors.

After a successful test has been made on one unit, the circuit automatically associates itself with the next by advancing the district or office selector, and proceeds in this manner until all have been tested. The attendant, by operating a key, may—if he desires—cause the test circuit to pass any unit being used for regular service, or he may arrange the test circuit so that when a busy unit is encountered the circuit will wait for the unit to be released and then apply a test, so that all of the units are tested on a single round. On some circuits of this class it is necessary to send a number of calls in order to make a complete test of a unit, since a single test call will not test all the various functions of circuits. When trouble is encountered on any unit being tested, an audible signal is given to call the attendant's attention.

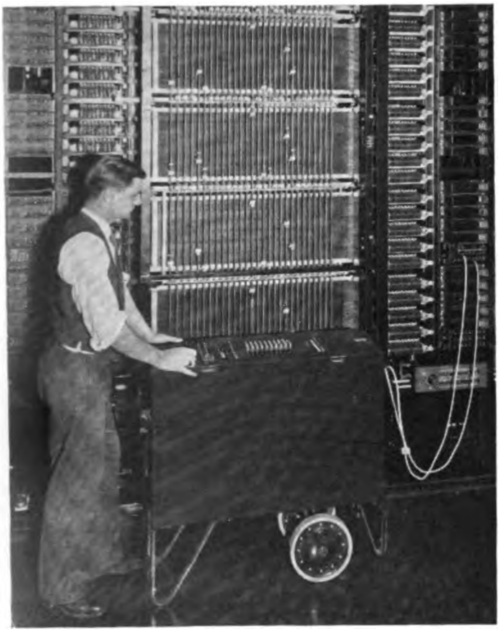


Fig. 2—A portable test set of the "tea-wagon" type is here being used to test an incoming selector

Since automatic test circuits require attention only in the event of failure, and for manipulating keys to start each round of tests, a substantial saving in attendants' time is accomplished; most of the time the test frame is functioning without attention. As a result of the economies effected by their use in the panel system, automatic test circuits are now used for testing senders associated with cordless "B" boards in the step-by-step system and it is possible that in the future automatic testing equipment may prove economical for other step-by-step circuits.

Many factors must be considered to determine when it is economical to provide a test circuit of the automatic class. The decision depends on the number of units to be tested, the frequency with which tests are required, the ease with which an automatic test circuit can be connected to the unit to be tested, and the relative costs of automatic and manual test circuits.

Where it is felt that a test circuit should be available, but the situation does not warrant an automatic circuit, portable test sets are provided. A photograph of such a set for testing office, incoming, and final selectors is shown in Figure 2. Another

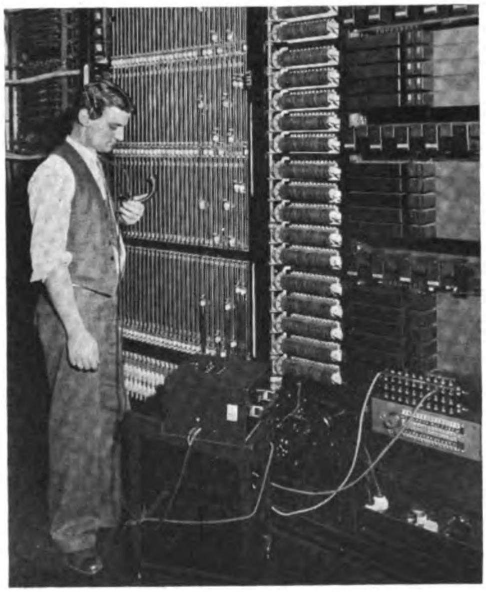


Fig. 3—Smaller than the "tea-wagons" are the box-type test sets, one of which is shown here in use at a B-position incoming-selector frame

type of portable set, shown in Figure 3, is employed for testing the incoming selectors used for calls that originate in a manual office. Where a sufficiently large number of units is used, and where some features of the unit could not be tested with an automatic testing circuit, both portable and automatic test sets may be provided. When a portable-type test set is used, it is taken to the location where the unit to be tested appears, and is then connected to the unit to be

tested by means of cords and jacks. Since attendants are at hand when the set is in use, visual indications are given when a successful test has been made or when trouble is encountered.

Routine test-circuits are also used as a method of definitely locating the cause of a trouble, since the maintenance man may observe the action of a unit while test calls are being made. This is the case with both automatic and portable types. To use the automatic circuits more effectively for this purpose, jacks for controlling the starting of test calls are provided at the frames where the units being tested are located. A series of calls may thus be made under the control of the maintenance man while he is observing the action of the unit under test.

Graphical Symbols for Telephone and Telegraph Use

By W. L. HEARD
Systems Development Department

GRAPHICAL symbols are the means by which information is recorded and transmitted when audible methods are not suitable or desirable. The ideograms of the earlier languages, like the Egyptian hieroglyphs, are such primitive symbols used for conveying general information. These, in the course of evolution, become formalized, and eventually only sound symbols remain, which are the words of ordinary writing. Although ideograms are not used in the modern languages, they perform an important role in the language of engineering drafting.

In making drawings, material objects must be indicated. A complete and correct sketch of each piece of equipment referred to would require too much time and space to be desirable, so that a symbol — a few lines perhaps representing the essential features of the object — naturally takes its place. In the degree to which they resemble the objects they stand for, drafting symbols differ widely. Some could never be mistaken for any but the thing they represent, but others are highly formalized and difficult to interpret. Symbols of this formalized type are suitable only when all those who will use the drawing are familiar with the conventions used.

For their effective employment, therefore, it is essential that symbols be standardized. There must be an agreement between those who use them as to their form and definition, and once standardized the use of the accepted symbol should be made as nearly universal as possible. To produce this standardization among the symbols used in the telephone and telegraph industry a committee was appointed some time ago under the chairmanship of W. E. Farnham of the American Telephone and Telegraph Company. On this committee were A. B. Smith of the Automatic Electric Company, H. W. Drake of the Western Union Telegraph Company, L. F. Shea of the New York, New Haven and Hartford Railroad, and the writer — representing Bell Telephone Laboratories.

This committee, representing very

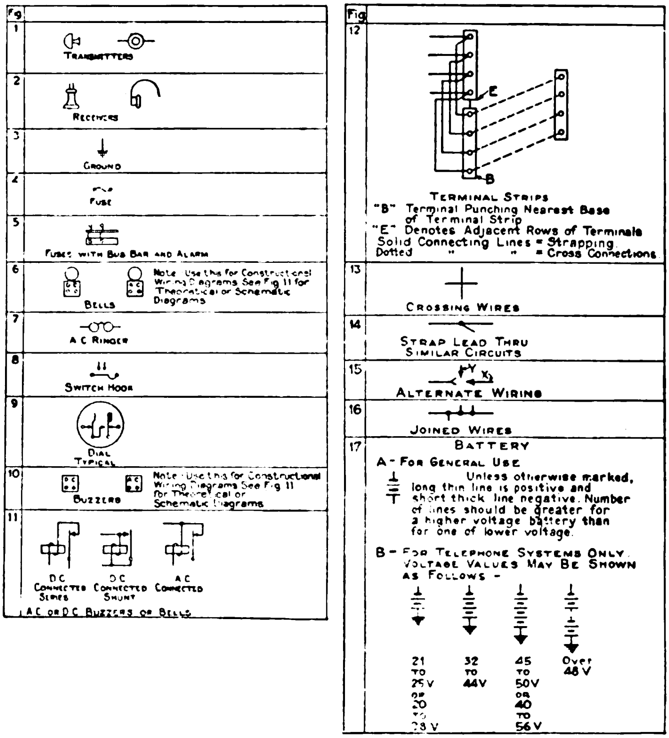
fairly the telephone and telegraph industry of the United States, acted as a part of a comprehensive national standardization organization which came into existence over ten years ago. The importance of having national standards can not be over-estimated and with the object of obtaining them, the American Standards Association (formerly American Engineering Standards Committee) was founded in 1917, at the instigation of the technical and scientific societies. Its duties are to investigate suitable subjects for standardization, and to appoint sectional committees, representing the industries and interests involved, which undertake the actual standardizing work. The A. S. A. itself does no actual work in creating the standards, but accepts and gives the stamp of national approval to those finally agreed upon by the sectional committees.

Following this prescribed procedure a sectional committee was appointed early in 1926 to agree upon standards of Engineering Symbols and Abbreviations. Owing to the wide scope of the undertaking, seven sub-committees were appointed to work in different fields, and some of these sub-committees were further divided. The committee on Telephone and Telegraph Symbols was a branch of the sub-committee on Electro-technical Symbols and Abbreviations. It was appointed in June, 1926, and completed its work late last summer.

As part of its procedure the A. S. A. appoints one of the national scientific or engineering societies as sponsor for each group of standards, and the American Institute of Electrical Engineers was naturally chosen guardian for the sub-committee of Telephone and Telegraph Symbols.

STANDARDS
OF THE
American Institute of Electrical Engineers

GRAPHICAL SYMBOLS FOR TELEPHONE AND TELEGRAPH USE
(Adopted by the Board of Directors, A. I. E. E., December 7, 1928)



The complete standard consists of forty-nine figures of which seventeen are shown on this first page. Some of the individual figures, however, have a large number of derivative symbols

It accepted the report of the sub-committee in December, 1928, and by doing so made the standards agreed upon the official standards of the A. I. E. E. These have now been printed and the first page of the standards issued is reproduced in the accompanying illustration. These will shortly be accepted by the A. S. A. and become, in addition, national standards.

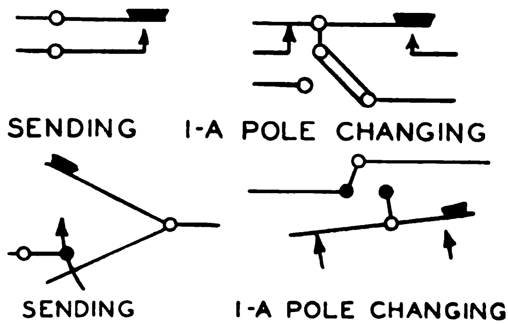


Fig. 1—Symbols for telegraph keys in the adopted standard differ from previous Bell System standards to a greater extent than any of the others

In the selection of telephone and telegraph symbols it is natural that those in use by the Bell System should have been adopted to a very large extent. In some cases, however, this did not seem advisable for one reason or another. The symbols for telegraph keys might be cited as an example. On Figure 1 the symbols used until recently by the Bell System are shown at the top, and beneath, those adopted by the committee. A slight change in the symbol for the telephone headset, shown by Figure 2, was another of the deviations from Bell System practice.

The completed assemblage of symbols combines, therefore, not only what has proven to be a most effective group of symbols during the half century of telephone development by the Bell System, but what a representative committee of the telephone and telegraph industry feels to be the most effective for continued use. By their adoption the language of the telephone drawing has become a standard means of imparting knowledge. Engineering standards and symbols, however, are subject to continual growth and evolution. Any standardization is of only relative permanency, and represents but the best present practice. It is hoped that from time to time valuable suggestions will be received which will result in still further improvement.

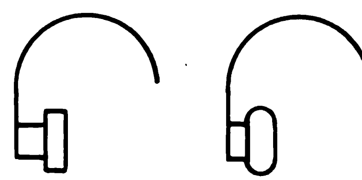


Fig. 2—The change made in the symbol for a telephone headset only changes the Bell System standards to a greater extent slightly alters the proportions

Trouble Indicator

By R. MARINO
Systems Development Department

OPERATORS are effective watch-dogs for the manual system. Most forms of trouble can not exist on a line for any length of time without their detecting it, and as soon as they perceive trouble, the maintenance force is notified, and steps are taken to remove it. With the introduction of the dial system this service that the operator performs was lost and it was desirable to devise something to take its place. As a part of a system used to guard decoders* and their immediately associated equipment from trouble is the trouble indicator.

In a dial system office most of the mechanical equipment is maintained with specially designed auxiliary test circuits. These exercise the apparatus under conditions generally more severe than those met in actual service and if trouble occurs during such a test, it is corrected by a maintenance man. This system of routine testing works very well when the units are small and trouble, as a result, is distributed over a large number of circuits each handling but a small fraction of the total office load. A district selector, for example, handles only 136 calls a day on the average, there being about 1100 of them in a 10,000 line office. Trouble developing in a selector immediately after the completion of the routine test could cause, therefore, only 136 cases of trouble—assuming daily routining—which is only one-tenth of one percent of the 150,000 calls constituting the average office traffic. Actually, of course, this is an extreme case as maintenance records indicate that the trouble for an entire office from all causes is not much higher than this.

With the decoder, however, the case is quite different. It may handle nearly 80,000 calls a day, so that a persistent trouble condition occurring soon after a routine test might seriously affect a large percentage of the office traffic for the day. Evidently, therefore, the routine test method of maintaining office equipment would not be an economical way of keeping the decoder free from trouble. Trouble occurring on it must be found and eliminated at once. This is done by a circuit which tests the decoder during the progress of every call, and the trouble indicator acts as a permanent sentinel, forever ready to display to the maintenance force any trouble that occurs. As soon as the decoder gets into difficulty, the trouble indicator is automatically connected, an alarm sounded, and the source of trouble flashed out on a group of lamps provided for the purpose.

There is in the decoder an arrangement known as the "second trial" feature which causes it, before acting on any call, to test its own equipment once. If trouble is found—false grounds, open wires, crosses, or ap-

* *The Decoder by R. Raymond, May,* 1928.

paratus in faulty adjustment—it refuses to act; the sender is signalled to select another decoder before completing the call, and the faulty decoder is temporarily held busy. This "second trial" feature is intended to enable a subscriber to get the number on his first attempt even though faulty apparatus were connected to the line. Much of the trouble occurring in the decoders is eliminated in this manner without the help of the trouble indicator because it is of a transient nature.

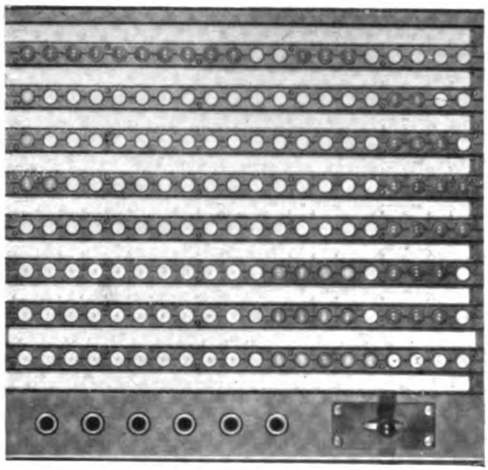


Fig. 1—From the outside the trouble indicator appears as a group of indicator lamps, red, white, or green in color. The above is a photograph of an early model

The trouble indicator itself consists of about fifty relays, each of which controls a lamp, and the whole unit is so arranged that it may be connected to any of the decoders through the operation of a multi-contact relay associated with each decoder. There is thus only one trouble indicator in each office. Whenever a decoder fails to complete its operation in a prescribed interval of time this master switching relay is operated and connects the relays of the trouble indicator to the decoder in such a way that the point of fault in the decoder will be shown by the lamps of the indicator.

This is made comparatively simple by the circuit arrangement of the decoder. Its relays operate successively so that failure of a relay to operate indicates that trouble exists on the connection between the last relay that operated and the one that has failed to operate. The relays of the indicator are so connected to the decoder that its lamps indicate the operation or non-operation of relays in the decoder electrically located at strategic points in the circuit, so that the trouble must be between one of these relays and the next one in the sequence.

The particular group of relays that operates in the decoder depends on the number being called, and the relay sequence for each call may be different. The trouble indicator shows whether or not certain of the relays in the decoder have operated. For most causes of failure it also indicates the office code dialed by the subscriber as well as the number of the decoder, sender, and connector used, as a further aid to the maintenance man. As soon as this information has been locked-in on the indicator, the decoder is disconnected from it and the information remains displayed until it has been manually released.

It is not expected that the maintenance men will investigate every trouble condition recorded on the trouble indicator as many of them are of a transient character and clear themselves without attention. It is only when troubles come in rapid succession that the attention of the maintenance force is likely to be needed. In order to discriminate between transient and permanent trouble, a

double alarm is furnished. One rings when the indicator is first used and ceases when the maintenance man has released it. The other rings only when a second case of trouble has developed before the indicator has been released. This repeated trouble within a short interval of time is the real danger signal as it generally shows that trouble exists that is not transient.

In this manner, the decoder circuit may always be kept in first class condition without requiring routine tests at short intervals of time as would be necessary were reliance to be placed on routining for keeping the decoders at all times fit for service.



A laboratory for the study of radio communication

News Notes

AT THE ANNUAL MEETING of The Museums of the Peaceful Arts held on February 27, 1929, Dr. Jewett was appointed an Honorary Vice-President of the corporation.

F. B. JEWETT AND H. P. CHARLESWORTH attended the Greater New Jersey Dinner given by the New Jersey State Chamber of Commerce and the New Jersey Bell Telephone Company on April 4, 1929, in the auditorium of the new State telephone headquarters building at 540 Broad Street, Newark, New Jersey.

F. B. JEWETT, T. G. MILLER, LLOYD ESPENSCHIED AND O. E. BUCKLEY, all of whom sailed for England on February 9, returned to New York on the Ile de France on March 26. The trip was made in the interests of transatlantic telephone communication and, while abroad, visits were made to England, Ireland, Germany and France. In England discussions were held with various officials of the British Post Office regarding additional long- and short-wave radio channels, as well as the problems in connection with the proposed transatlantic telephone cable. Dr. Jewett also discussed with officials of the French and German Telegraph and Telephone Administrations the question that they had previously raised regarding direct radio-telephone communication between their countries and the United States.

PROFESSOR A. SOMMERFELD of the University of Munich addressed the members of the Coloquium on April 9. His subject was "The Photo-electric Effect in a Single Atom and in a Metal." At the April 1 meeting, E. F. Kingsbury spoke on "Physical Problems of Making and Breaking Electrical Contacts."

MR. CHARLESWORTH has been appointed to represent the American Institute of Electrical Engineers on the Board of Awards of the Alfred Nobel Prize, which is awarded each year by the American Society of Civil Engineers for the most meritorious technical contribution submitted by a member of one of the four founder societies which represent civil, mechanical, mining and metallurgical, and electrical engineering.

MR. CHARLESWORTH AND MR. MILLS attended the Bell System Publicity Conference held April 10 to 17, at the Mid-Pines Club, Pinehurst, North Carolina.

DURING the All American Aircraft Show, held in Detroit from April sixth to fourteenth inclusive, the Laboratories cooperated with the Western Electric Company in demonstrating the new 6008-A Radio Receiver described in the April RECORD. The party from the Laboratories comprised R. L. Jones, O. M. Glunt, E. L. Nelson, F. M. Ryan, J. O. Gargan, D. K. Martin, R. S. Bair, S. E. Anderson, W. C. Tinus, and H. B. Fischer.

Men prominent in the aircraft industry were taken up in the Laboratories' plane and allowed to listen to the hourly weather reports broadcast from Cleveland, and also to the radio beacon while flying toward the Ford

airport at Dearborn. Among those taken up was Captain F. C. Hingsburg of the Lighthouse Bureau of the Department of Commerce who has charge of radio stations and airways.

Apparatus Development

D. D. Miller recently addressed a convocation of the Apparatus Development Department on "The History and Recent Developments in Electromagnetic Apparatus." He described various relays, including the flattened core type invented by Mr. Craft, and emphasized the fact that relays and other electromagnetic apparatus represent the largest item of expense in telephone apparatus. W. Fondiller presided and R. L. Jones spoke on the general organization of functions of the department.

E. C. Erickson spent the week of March 25 at Hawthorne developing methods for the measurement of diaphragm dimensions.

H. N. Van Deusen, J. M. Wilson, J. R. Townsend and C. H. Greenall attended a conference on specifications for copper alloy sheet materials with representatives of the Northern Electric Company, Western Electric Company and American Brass Company, at Montreal.

J. R. Townsend visited Hawthorne to discuss the manufacture of the light valve for sound pictures and also fatigue of sheet metals.

H. A. Anderson discussed the problems of welding loading coil cases and heat treatment of dial parts at Hawthorne during the week of March 18. While in Chicago, he attended with J. R. Townsend committee meetings of the American Society for Testing Materials on die casting and fatigue.

E. Montchyk spent the week of March 18 in Denver studying cleaning methods for step-by-step banks of a local dial office. On the return trip he spent several days at Hawthorne in connection with problems of apparatus development.

D. W. Mathison made a study of cleaning methods for dial apparatus terminals at Lansing, Michigan, during the week of March 11.

J. N. Reynolds investigated enameling processes at the Porcelain Enamel Manufacturing Company at Baltimore, Maryland.

G. W. Folkner and J. N. Reynolds visited the new step-by-step installation at Wilmington, Delaware, on April 2.

D. D. Miller and H. F. Dobbin discussed compressed air apparatus with representatives of the National Pneumatic Company of Rahway, New Jersey on March 20.

J. F. Hearn was at Hawthorne in connection with the manufacture of gear-driven sequence switches and die-cast drive-shaft bearings.

G. B. Baker recently investigated developments in step-by-step relays at Hawthorne and at the Automatic Electric Company in Chicago.

W. T. Pritchard attended a conference on April 4 with representatives of the American Telephone and Telegraph Company and the Bell Telephone Company of Pennsylvania on maintenance apparatus for the panel dial system.

E. B. Wheeler spent a week during March at Hawthorne, in connection with the development of switchboard cable and enameled wire.

A. B. Bailey directed the installation of the new antenna system at Station WABC of the Columbia Broadcasting System at Broad Channel, New York.

N. Bishop inspected the one-kilowatt broadcasting equipments of the Fisher Blend Station, Inc., and the Puget Sound Broadcasting Company at Seattle, and the Oregon State Agricultural College at Corvallis. He inspected the one-kilowatt broadcasting equipment and made a survey for the proposed five-kilowatt broadcasting equipment for Louis Wasmer, Inc., Spokane, and supervised the conversion to crystal control of the one-kilowatt broadcasting equipment of the Oregonian Publishing Company, Portland.

B. R. Cole made a survey for a five-kilowatt broadcasting equipment of the Atlanta Journal, Atlanta, Georgia.

J. C. Herber made a survey for the five-kilowatt broadcasting equipment purchased by Larus and Bro., Inc., of Richmond, Virginia. He inspected the five-kilowatt broadcasting equipment of the Missionary Society of St. Paul the Apostle, Kearny, New Jersey.

O. W. Turner supervised the installation of the one-kilowatt broadcasting equipment of the Shepard Stores, Boston, Mass. He inspected the one-kilowatt equipments of the Outlet Company, Providence, and the Matheson Radio Company, Gloucester, Massachusetts.

C. D. Hocker, C. S. Gordon, F. F. Farnsworth and E. M. Honan attended a committee meeting of the American Society for Testing Materials held in Chicago during the week of March 18. Mr. Hocker extended his trip to Kansas City to visit the clay products plant of the W. F. Dickey Manufacturing Company while Mr. Gordon and Mr. Honan visited Hawthorne to observe wire development.

W. H. S. Youry spent the week of March 18 visiting the Hermann Oak Leather Company of St. Louis and the R. H. Buhrke Company of Chicago in connection with the manufacture of body belts and safety straps.

F. F. Farnsworth and H. Baillard visited the James A. Kiley Company in Boston during the week of March 11 in connection with field tests of paints for automobile trucks. During the following week Mr. Baillard made similar observations in Cleveland, Ohio.

G. Q. Lumsden made an inspection of preservative-treated poles in the territory of the Mountain States Telephone and Telegraph Company.

C. Shafer visited the Southern New England Telephone Company in New Haven during March to make studies of drop wire.

Inspection Engineering

A. F. Gilson, R. M. Moody and D. S. Bender visited Boston on March 22 to conduct an investigation of switchboard keys.

R. M. Moody and H. C. Cunningham attended a survey conference at Kearny in connection with telephone cords during the week of March 11. Mr. Moody and C. J. Hendrickson visited Hawthorne during the last week of March to attend a similar conference for the study of dial apparatus.

S. H. Anderson attended a conference for the study of inspection and quality of protective devices at Hawthorne.

W. E. Whitworth, Omaha Field Engineer, visited Denver, Colorado, and Gothenberg, Sidney, and North Platte, Nebraska, in connection with Field Engineering activities.

E. G. D. PATTERSON AND A. F. GILSON visited the Highway Trailer Company in Edgerton, Wisconsin, during the first week of April to conduct quality studies of automotive equipment.

O. S. MARKUSON, AND A. G. HALL of the Outside Plant Development Department, visited Kingston, New York, to observe the installation of the first 1800-pair lead covered cable manufactured at Kearny.

SYSTEMS DEVELOPMENT

B. W. KENDALL spent several days in Ottawa, where he testified in connection with patent matters.

H. M. PRUDEN investigated 1000-cycle signaling equipment in Philadelphia and Harrisburg.

E. VROOM inspected pilot-wire regulating equipment at the repeater station in Kingston, New York.

D. M. TERRY, W. F. KANNENBERG, G. H. HUBER, R. W. CHESNUT AND F. A. MINKS have been engaged in testing between Washington and West Palm Beach an improved automatic pilot channel for carrier telephone systems.

C. C. LANE inspected the new telephone typewriter service at Chicago. A. D. Dowd and J. E. Zendt inspected a similar service in Boston.

F. J. SCUDDER AND S. F. BUTLER spent several days at Hawthorne, discussing new tandem installations.

F. A. KORN, A. H. LINCE AND G. K. SMITH visited Atlantic City to investigate new step-by-step equipment at the Marine Central Office, and to observe PBX operation in several hotels.

R. W. HARPER conferred with representatives of the Stromberg-Carlson factory at Rochester on the manufacture of the 506-A PBX.

L. M. ALLEN, F. T. MEYER, J. R. KIDD AND J. R. JACKSON made a trial installation of subscriber sets for rural line equipment, at Albany, Olean and Troy.

J. E. GREENE made a trial installation of out-trunk pre-selector equipment in the Number 5 office at Syracuse.

W. G. SCHAER discussed improved central testing bureau equipment with engineers of the Western Electric Company at Hawthorne.

R. E. NOBLE AND C. E. BOMAN inspected a new form for supporting frames in central offices at Wilmington, Delaware.

H. M. SPICER discussed various power problems with engineers of the General Electric Company at Schenectady.

PATENT

Members of the Patent Department who visited Washington during the period from March 10 to April 9, 1929, were H. A. Flammer, H. P. Franz, E. V. Griggs, A. J. Michel and J. W. Schmied.

RESEARCH

W. C. JONES AND N. BLOUNT were at Hawthorne for conferences on the design of transmitters.

P. A. LASSELLE attended a conference at Hawthorne on flame baking of enameled wire.

J. H. INGMANSON attended the meeting of the American Society for Testing Materials in Chicago and also visited Hawthorne in connection with the development of rubber covered wire.

H. H. LOWRY AND W. ORVIS visited certain properties of the Jeddo-Highland Coal Company at Hazleton, Pennsylvania, on March 28 and

29, to investigate a new supply of coal for the manufacture of transmitter carbon.

R. M. BURNS conferred on metal finishes with engineers at Hawthorne, later going to Milwaukee to observe experimental research on paints at the Pittsburgh Plate Glass Company.

L. H. CAMPBELL examined paint testing equipment at the Munsell Color Company in Baltimore.

C. L. HIPPENSTEEL visited Hawthorne to confer on problems of metal finishes, and attended committee meetings of the American Society for Testing Materials in Chicago.

H. E. IVES addressed a meeting of the American Physical Society in Washington, April 18, on "Motion Pictures in Relief."

HARVEY FLETCHER gave a lecture and demonstration in the auditorium on "Speech and Hearing," on Tuesday, March 26, before the Columbia Chapter of Sigma Xi and their guests.

W. A. MARRISON presented a paper on *A High Precision Standard of Frequency* at the symposium on frequency measurements held in New York by the Institute of Radio Engineers on April 3. He also gave a paper, *Oscillograph for Recording Transient Phenomena* at the A. I. E. E. Spring Convention at Cincinnati.

T. C. FRY visited Brown University to interview engineering students of the class of 1929.

F. R. LACK was the author of a paper, *Observations on Modes of Vibrations and Temperature Coefficients of Quartz Crystal Plates,* given before the Institute of Radio Engineers.

AT THE WASHINGTON MEETING of the American Physical Society held April 18 to 20 at the Bureau of Standards and the National Academy of Sciences, papers were presented by six member of the Research Department. These were: *Determination of the Average Size of the Discontinuities in Magnetization,* by R. M. Bozorth; *Magnetic Properties of Iron Crystals,* by D. D. Foster; *Use of Dielectrics to Sensitize Alkali Metal Photoelectric Cells to Red and Infra-Red Light,* by A. R. Olpin; *The Preparation of Photoelectric Cells with Thin Films of Lithium as the Photoactive Material,* by H. E. Ives; *Thermionic Emission as a Function of the Amount of Adsorbed Material,* by J. A. Becker; and *The Equilibrium between Surface and Volume Concentrations of Dissolved Substances,* by J. M. Eglin.

GENERAL STAFF

S. P. GRACE spoke before the Engineers Club of Philadelphia on April 12. On April 18 he addressed the Boston City Club, and on April 23, the Yale Branch and Connecticut Section of the A. I. E. E. at Yale University. R. M. Pease, of the Apparatus Development Department, made the demonstrations.

P. B. FINDLEY'S lecture engagements for April included a series of talks at Cleveland on the development of sound pictures. He addressed a luncheon meeting of the Advertising Club of Cleveland on April 17, and on the following day the student body of Case School of Applied Science. In the evening he addressed a meeting of the Cleveland Section, A. I. E. E., to which the public was invited. On April 19, he talked to about two hundred telephone people. W. C. F. Farnell was in charge of the demonstration of sound pictures, and with Mr. Findley was a guest at a dinner tendered by the Ohio Bell to officers of the Institute section.

R. A. DELLER delivered a lecture on television, and demonstrated television apparatus, at Rensselaer, New York. The audience consisted of faculty members and students of Rensselaer Polytechnic Institute.

CONTRIBUTORS TO THIS ISSUE

L. G. BOSTWICK received the B. S. degree in electrical engineering from the University of Vermont in 1922. From 1922 to 1926, with the Development and Research Department of the American Telephone and Telegraph Company, he was concerned with general problems on systems for the high quality transmission of speech and music. In 1926 he was transferred to the Research Department of these Laboratories, to work on loud speakers.

H. A. BURGESS received the A.B. degree from the University of Syracuse in 1914. After two years with the Government Bureau of Standards and with the Government Patent Office, he joined the Patent Department of these Laboratories in 1919. Here Mr. Burgess is concerned with patent problems affecting developments in general transmission, carrier transmission and repeater circuits.

AFTER obtaining the degree of B.S.E.E. from Kansas State College in 1911, W. L. Heard entered the employ of the Automatic Electric Company in Chicago. The next year, however, he became affiliated with Western Electric in Hawthorne and remained with them until 1919 when he was transferred to the Laboratories. Both at Hawthorne and in New York, his work has been equipment engineering, and he is now Equipment Methods Engineer.

I. H. GERKS joined the Technical Staff of Bell Telephone Laboratories on leaving the University of Wisconsin, where he was graduated with the degree of B.S. in 1927. His work here has been with the Systems Development Department chiefly on ringing and tone studies.

R. MARINO received the degree of Bachelor of Science from the College of the City of New York in 1918 and shortly after joined the Laboratories' Technical Staff. Subsequently he received the degree of Electrical Engineer from the Polytechnic Institute of Brooklyn, and that of Doctor of Jurisprudence from New York University. His work with the Laboratories has been in the laboratory end of the Systems Development Department, where he has participated in the development of various machine-switching circuits.

R. C. PAINE joined the Bell System in 1921, in the Installation Department of Western Electric, with headquarters at West Haven, Connecticut. In 1923 he came to the Engineering Department, in the Local Systems Laboratory, and in 1926 was transferred to a group engaged in design of local circuits, in the Systems Development Department. Mr. Paine secured his engineering training at Glasgow University, Worcester Polytechnic Institute, and Webb Institute of Naval Architecture.

L. M. ALLEN joined the Laboratories' technical staff in 1919 after extensive operating experience. With the New York Telephone Company he held various positions from 1906, when he was engaged in maintenance work, till he was transferred to the Laboratories, when he was Night Wire Chief for the Manhattan and Bronx Division. He is now Field De-Development Engineer in the Systems Development Department.

Bell Laboratories Club



The Equipment basketball team decided that a cup should have three legs to stand properly and, having won two, proceeded to defeat the Tube Shop team on April 2 at Labor Temple, thereby taking permanent possession of the trophy symbolic of the championship of the Interdepartmental League. The game was fast and furious, featured by some pretty shots, and when it was all over the score stood 29 to 20. The players played in deadly earnest, and for a time it appeared that Referee Maurer, despite his good control in the league games this season, might throw away his whistle for a more suitable gong. The game was close throughout, causing grave doubts as to whether the bronze trophy, won by the Equipment team in 1927 and 1928, would maintain its majestic place in H. H. Lowry's office. In fact, some of the partisan executives' fears extended to demonstrating between periods some of the more elusive methods of making shots from the floor. Noted among the large number in attendance were H. P. Charlesworth, A. F. Dixon, R. L. Jones, H. H. Lowry, G. B. Thomas and O. M. Glunt.



The members of the winning team, including Messrs. O'Neil, Michal, Trottere, Kuenzler, Maloney, Reinberg and Arnold, as well as the most valuable player on each of the other teams of the League, will receive wallets as a reward for their distinguished efforts. A. Kontis of the Tube Shop team also was the winner of the silver trophy given to the player scoring the greatest number of points during the season. Kontis was credited with 119 points, eclipsing the next leading scorer, Trottere, by 37 points.

Watches for Golfers

Did you ever try to drive a golf ball off the face of a watch? Some pros can do this but we don't expect our Club golfers will want to try it with the wrist watches to be given as prizes at the spring tournament. This will be held at the Salisbury Country Club, Garden City, L. I., on the first two Saturdays in June, the qualifying round taking place on June 1 and the finals on June 8.

The committee feels that it now has a very good record of the scores of most of the Club golfers from previous tournaments. It is planned, therefore, to conduct this tournament in a different way from previous tournaments. All those entering the tournament will be classified according to handicaps and will compete in the qualifying round in three classes. The makeup of the classes will be as follows:

Class A—Handicaps of 20 or under.
Class B—Handicaps of from 20 to 32 inclusive.
Class C—Handicaps of from 33 to 35.

There will be the usual prizes for low gross and low net scores in the qualifying round.

The number of golfers to qualify in each class will be determined by the number of entries in each class. Total number to qualify will be 30.

Another change is to award prizes for the finals on the basis of total scores for 36 holes instead of only final scores as in previous tournaments.

Entries should be filed with D. D. Haggerty or J. C. Kennelty before May 25. The entrance fee is $2.00.

Down the Cinder Path

Preparations are under way for the track and field meet of the Bell System Athletic League to be held at Erasmus Hall Field, Brooklyn, on Saturday afternoon, June 22. The Laboratories usually produces some very competent talent for the Bell System Meet, and prospects for a good showing are bright.

Prizes, as well as the thrill of competition, will be the lure for our athletes. Men and women are urged to come out for the various events. Try-outs for the Laboratories Club Team will be held at Erasmus Field on Saturday afternoon, May 25. The Laboratories Club may enter three competitors in each event in the League Meet, and a full quota will be selected at the try-outs.

The events to be contested in the meet are as follows:

Men's Team

100 yard Dash	Shot Put
220 yard Dash	Broad Jump
440 yard Dash	High Jump
880 yard Run	Tug-of-war

1 Mile Relay

Women's Team

60 yard Dash	Quarter Mile Relay

Basketball Throw

First prize in the League Meet for the winners of each of the men's events, with the exception of the tug-of-war and the mile relay, will be an Elgin wrist watch. The first prize in the relay and tug-of-war events will be a valuable wallet. Silver medals will be given to the winners of second place and bronze medals will reward the winners of third place in all the events. Prizes of equal value will likewise be given to the winners in the women's events. In addition, the Laboratories Club will give suitable prizes to the winners of the events in the try-outs for the Club Team.

N. H. Thorn, L. P. Bartheld and D. D. Haggerty will endeavor to keep things in hand at the meets.

Handball Par Excellence

The Handball Tournament ended in a blaze of brilliant playing after a succession of hotly contested eliminations, which took place Tuesdays and Thursdays during March. "Tip" O'Neil, winner of the tournaments of 1927 and 1928, again displayed his alacrity on the court and came through in the forefront of the twenty-four men who competed. Some of the match play was of professional character as to speed, accuracy and technique.



In the semi-final, Schmitt met defeat at the good hands of Krazinski after three close games. O'Neil then overcame the opposition of the winner in straight games to clinch the championship for the third successive year.

One object of the tournament was to develop talent for a team to represent the Club in competition with out-

side teams. There is no doubt that the objective was attained with something to spare.

Notable Chess

In a setting reminiscent of the country store, with desks and file cases serving for cracker boxes and barrels, and chess for checkers, the players of the Club Chess Team meditatively matched wits with Hawthorne in the annual match by printing telegraph April 6th, and when decks were cleared, far into the night, after ten hours of play, had won the verdict, six games to four.

The Club won four of the games, drew four and lost two. C. F. Sacia, leader of the Laboratories players, was the first to finish and won in eighteen moves. He was followed with like results by H. M. Stoller, H. D. Cahill and T. Slonczewski. Draws were scored by F. A. Voos, D. A. Quarles, H. T. Reeve and G. H. Heydt. Mr. H. Helms, editor of "The American Chess Bulletin," was the referee. The summary:

Bell Laboratories

Boards		
1.	C. F. Sacia	1
2.	F. A. Voos	½
3.	H. W. Bode	0
4.	D. A. Quarles	½
5.	H. M. Stoller	1
6.	H. T. Reeve	½
7.	H. D. Cahill	1
8.	T. Slonczewski	1
9.	G. H. Heydt	½
10.	H. W. Wood	0
	Total	6

Hawthorne

Boards		
1.	J. M. Juran	0
2.	J. Shallcross	½
3.	A. V. Cederquist	1
4.	C. R. Masmussen	½
5.	F. Asplund	0
6.	R. D. Warth	½
7.	A. Birkland	0
8.	H. L. Morgan	0
9.	L. H. Warth	½
10.	H. Brandner	1
	Total	4

A chess match of extraordinary interest was played on February 28, when Mr. Frank Marshall, noted international expert and United States champion, in simultaneous match play with thirty members of the Club Chess Team defeated twenty-eight players. Mr. H. T. Reeve and Mr. E. G. Andrews, the other members of the team, succeeded in getting a draw with the champion.

Many of these men are members of the Laboratories Club Chess Team playing in the Commercial Chess League of New York, and have shown considerable prowess in winning the championship of the League for six consecutive times over some of the strongest teams in this section.

Brighton Beach Swimming

Many are the ways that Laboratories people spend their spare time



during the summer months, but there is no doubt that swimming surpasses in popularity all other forms of recreation as soon as the warmer weather arrives.

With this in mind the Executive Committee of the Club has offered Club members and their friends for the past five years an opportunity to enjoy both outdoor and indoor swimming at greatly reduced rates.

Again this year, arrangements have been completed with the Brighton Beach Baths whereby Club members may purchase tickets from the Secretary at one-half the rate charged by the management. Tickets giving Club members all privileges on Saturdays, Sundays and holidays are now available. These tickets are one dollar each for Sundays and holidays and fifty cents each for Saturdays. Club membership cards should be presented with the tickets of admission.

Last season over one thousand Club members and their friends enjoyed the bathing at Brighton Beach and it is hoped that even more will take advantage of this opportunity during 1929. All department representatives can supply these tickets in any quantity.

Shelton Pool tickets will also be available during the summer months at the same rate charged by the hotel management during the fall and winter seasons. Tickets may be purchased from the Club Secretary for seventy-five cents, which is one-half the rate charged by the hotel.

Through the Lens

Our camera contingent became prolific in the Third Annual Photographic Contest and submitted some



150 prints. The awarding of prizes was made difficult by the high standard of work represented. In the Still Life class first and third prizes were awarded to the entries of E. Alenius, and second prize went to C. G. Scofield. For still life studies, some camera artists invaded the realm of the fairies and toadstools and captured instead likenesses of wraiths and ogres, much to the chagrin of the judges. In the Portrait class Mr. Scofield's entries took first, second and third prizes, showing original and effective treatment of the subjects. A large number of excellent landscapes were presented, and prizes in this class were divided as follows: first, E. Alenius; second, G. R. Lum; third, J. Popino. The mounting of the prints in many cases showed originality and exceptional good taste. The winning and most worthy photographs were placed on exhibit and received the acclaim of a throng of viewers.

W. A. Wolff of Western Electric and Margaret Horne and H. Maude of the Laboratories were the judges of the contest.

Tennis Racket

On May 13 our tennis artists will start their activities for the year with the first singles tournament to be held by the Club in many years. The arrangement of the tournament will differ from that of the doubles held last fall in that the players themselves will pay and arrange for the courts, and the matches of each round will be completed in the week following the completion of the previous round. There will be no entry fee. The Club will supply a new set of tennis balls for each match and will offer handsome first and second prizes to the winner and runner-up. A large entry list and keen competition is ex-



pected. In the fall, another doubles tournament will be held.

Some inquiries have been made concerning the possibility of holding a women's tennis tournament. Those who are interested should communicate with Marion Kane. Notices will appear on the bulletin boards.

Women's Swimming Class

Because of the increasingly large registration for the spring swimming class, it has been decided to devote three evenings a week to swimming at the Carroll Club; Monday, from 7:00 to 7:30 and Wednesday and Thursday evenings from 5:30 to 6:00 o'clock. Since there are now ninety-four girls interested, including thirty recruits from Hudson Street, the Club has engaged the services of Miss Alma Wyckoff, formerly of the Women's Swimming Association of New York, to assist Miss Spranger.

Miss Wyckoff will have charge of the instruction for beginners, while Miss Spranger will continue to teach the advanced pupils.

Women's Indoor Golf

The second indoor golf tournament for women was held at the Miniature Golf Course of America on March 27.

Catherine Maull, who had the low score of 104 strokes in the qualifying round, medal play, received a merchandise order on Peck and Peck.



Miss Maull was entered at scratch in the finals and each of the other contestants was given a handicap equal to three-fourths of the difference between her score and that of Miss Maull.

The first prize in the finals was won by Frances Post, who finished with a net 37; the second prize was awarded to Marie Egan with a net 41; and Marianne Grimm, Helen Norton and Mabel Wirsching tied for third place with a net 43. Each of these was given a prize of equal value.

If enough women are interested, the Club will arrange an outdoor golf tournament for them. Marian Kane, who can be reached on 774, will furnish particulars.

BELL LABORATORIES RECORD

TELEPHOTOGRAPHY IN ENGLAND
By L. A. O'Brien

VECTOR SLIDE RULE
By M. K. Kruger

ALL-RELAY REGISTER CIRCUIT
By R. Raymond

JUNE 1929 VOL. 7 NO. 10

Bell Laboratories Record

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Bell Laboratories Record

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Picture Transmission in England

By L. A. O'BRIEN
Systems Development Department

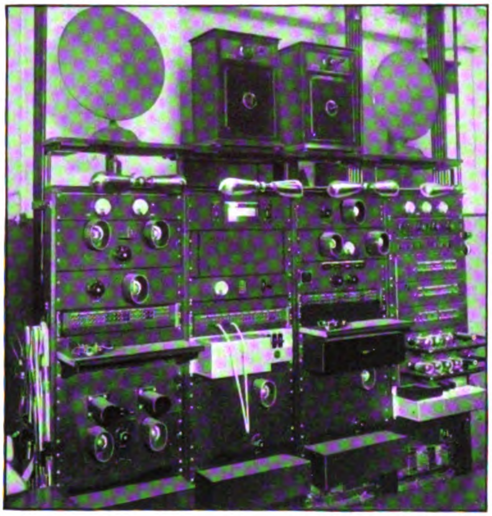
"GLASGOW, Start!" A second's pause,—"Manchester, Start!" When the operator at the picture transmission station of the *Daily Express* in London hears these signals from his monitoring loud-speaker, he presses the "start" key on the transmitting machine. Instantly, the film cylinders of picture machines in the publishing houses of the London Express Newspaper, Ltd., in London and Manchester, England, and in Glasgow, Scotland, start rotating in synchronism, and a picture passes over a telephone line from London to the other two cities.

Over lines of the British Post Office in England and Scotland there now operates* a Western Electric Type A Picture Transmission System for the London Express Newspaper, Ltd., publishers of the *Daily Express*. The main editorial staff and publishing house of this company are in London; branch publishing houses are at Manchester and Glasgow. Theirs is a high-class morning newspaper, with a daily circulation of over one and a half millions. Competition in the race for increased circulation is strong. The larger newspapers are national publications, distributing their issues throughout the British Isles. One would suppose that there was little need for electrical transmission of pictures in an area as closely knit as England and Scotland. But such systems are, in fact, of great value to these newspapers.

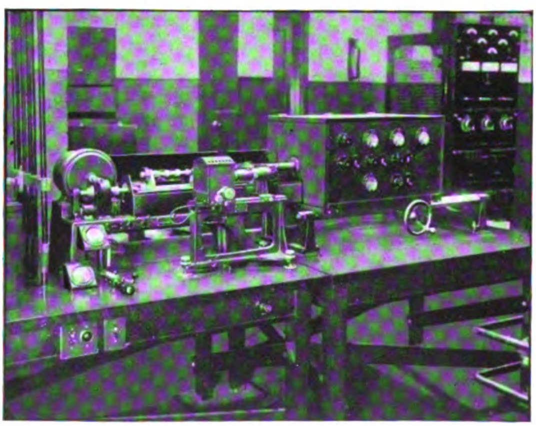
This value is largely accountable to special British news-geography. London is the news center for the Isles. Throughout the provinces widespread interest in London and international news prompts a demand for London newspapers, and the larger papers are edited with a view toward reaching all parts of the British Isles. Distance makes difficult the problem of distributing papers from London: to ship to some of the more distant points requires from eight to twelve hours.

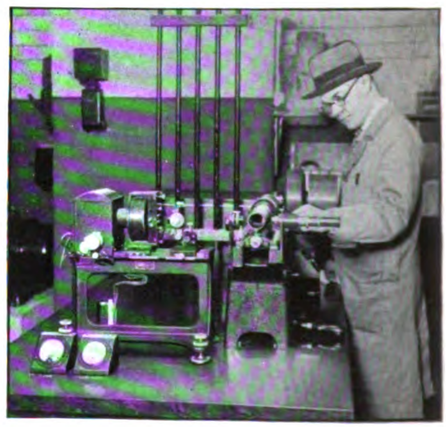
To avoid this delay, the leading

** F. G. Gardner and M. A. Byers of the Long Lines Department were associated with the writer in installing and testing this system and in training operators for it.*









Above, left, apparatus associated with the picture machines at Manchester; right, power switchboard and motor-generator of English manufacture, at the Manchester Station. Below, left, picture-transmitting machine and associated apparatus at Manchester; the posts supporting the tables on the floated cement block appear at the floor level. Right, operating the picture-receiving machine at Manchester

newspapers are establishing branch publishing houses in distributing centers throughout the country. The first-opened branch of the *Daily Express,* at Manchester, serves northern England and Ireland; quite recently a branch to serve Scotland opened in Glasgow. Most of the editorial work, preparation of advertising layouts, and the like, is done in London, and the copy is transmitted to the branch houses over printing telegraph systems. Papers are printed at the branches as nearly like the corresponding London editions as possible, except for local advertising and news.

Most of the leading papers feature a page of photographs and include a great many more in the news columns. The rapid transfer of these photographs between offices is difficult. Before the advent of picture transmission by wire, pictures lagged behind text, and news offices were unable to distribute "late" news photos to their branches in time for corresponding editions.

Wire transmission not only gives photos the speed of news but eliminates the duplication of "morgues": the files of portraits of persons in the public eye. Pictures filed in London can be transmitted to the branch publishing houses whenever their subjects come to the front in the news. The system also expedites the distribution of editorial cartoons based on current news and of layout information for display advertisements received shortly before the time for publication.

The Type A picture-transmission sets furnished the *Daily Express* are of the most recent design, resembling those used by the Bell System in this country. The engineering of the equipment for England was done at the Laboratories, and the machines and optical apparatus were made in its Engineering Shop. The remainder of the sets, except the power plants, was manufactured at the Philadelphia Instrument Shop of the Western Electric Company; and the sets were assembled and tested there before shipment to England. Storage batteries, power switchboards, motor-generators and the like were manufactured by English companies to meet the Laboratories' specifications, in order that the component parts would conform to the requirements



Route, over British Post Office lines, of pictures transmitted electrically by the Daily Express

of the English electrical code. To interconnect this terminal apparatus, transmitting facilities were adapted in cooperation with British Post Office engineers.

The picture-transmission stations at the London and Manchester of-



A picture, taken at the investiture of the Archbishop of Canterbury, after being transmitted from London to Manchester

fices are located in the basements of buildings which house large printing presses. It was necessary to take special precautions in installing the sets to prevent the vibration of the buildings by the operation of the presses from disturbing the picture machines and optical systems. Due to the nature of the soil, these buildings do not have foundations of the type in which the walls and column bases support the building; instead, the basement floor is made of concrete six or eight feet thick, and the entire building rests on this large concrete slab. In these buildings vibrations which are caused by the printing presses in one part of the building are transmitted quite effectively through the basement floor.

To insulate the table-mounted equipment from vibration, it was installed with the table legs resting on short posts, supported on a large concrete block which was "floated" on steel springs. The block, about eighteen feet long, five feet wide and three feet high, rests in a pit in the basement floor, with clearance of about a foot and a half at the sides and ends. Along each side of it, four sets of leaf springs engage the ends of steel beams cast into the block and support its weight. The pit was covered by a false floor with holes for the posts supporting the table legs. Building vibrations are absorbed by the springs supporting the block, and the picture machines are undisturbed.

The Type A system transmits five-by-seven inch pictures at a maximum rate of about eight per hour. At present the *Daily Express* leases the picture line circuit from the British Post Office for the period from 6.00 P.M. to 10.00 P.M. each day, and transmits an average of about fifteen and sometimes as many as twenty-four, pictures daily. When two or three small pictures can be copied photographically on one five-by-seven inch film, they are transmitted together. For economy and uniformity the pictures are retouched before transmission; retouching of received pictures is confined to those which are enlarged photographically for publication at greater size than that transmitted. Identification is secured by serial numbers marked on the original pictures before the transmitting films are prepared; the titles of the pictures are telegraphed. A letter prefixed to each serial number designates the publish-

ing house from which the picture was transmitted.

It is obvious that, if the photographic operations required in preparing the films for the transmitting machines, developing the films from the receiving machines, and enlarging the received pictures are not done correctly, the received pictures will not be of the best quality. Since a considerable volume of photographic work is involved, the processes must be systematized and a routine for handling the pictures efficiently must be established. At the *Daily Express* stations, a large sink with suitable tanks for the developing solutions and washing baths was provided in the operating rooms. While pictures are being received, the rooms are illuminated with "safe light" lamps, as photographic darkrooms are. The received pictures are developed by the station operators, following a standardized process. The operators can thus watch the pictures received and note any markings indicating faults in transmission, so that operating troubles can be detected before they become serious.

The remaining photographic operations were done for a while in the art departments. These groups had photographic facilities as necessities to their work before the picture transmission system was contemplated. But the increase in photographic work occasioned by the electrical transmission of pictures, and the importance of doing this work according to processes best suited to the Type A system, warranted the use of separate photographic equipment with the system. A camera room and developing room with carefully selected apparatus were recently provided at the London station for preparing the transmitting films and developing the



Another transmitted picture of the investiture of the Archbishop of Canterbury (crop markings appear at top and left)

received pictures. One photographer will devote himself entirely to this work. This specialized equipment and personnel will make the average picture as good in quality as only the best formerly were.

The initial installations of Type A equipment for the *Daily Express* comprised a two-way station at Manchester, a transmitting set at London, and a receiving set at Glasgow. Results with this equipment have been so gratifying that the *Daily Express* has ordered additional apparatus sufficient to provide for two-way operation at the London and Glasgow stations. The utility of picture transmission in Great Britain, the enthusiasm of newspaper organizations for its speed and quality, and the interest of the British Post Office in its growth, augur still wider future use.

Radio and Commercial Aviation

The rapid development of civil aviation has brought sharply to the forefront the vital importance of adequate means of communication between ground and air. Such communication is not only indispensable in directing the commercial operation of aircraft, but is particularly important as a means to the safety of the craft and its passengers, particularly during heavy weather.

The Bell System fully recognizes these needs and the obligation thereby imposed upon it for the development of proper methods and apparatus for these purposes; and it has been conducting for some time in the Bell Telephone Laboratories extensive and intensive research along these lines. It expects within a comparatively short time to be able to make available to the aviation industry through the Western Electric Company apparatus of a superior type to meet these needs.

Radio is obviously the means of communicating with aircraft in flight, and it has been found that radio telephony is the most effective way of carrying on such communication. The establishment of a connecting link by radio telephony between the aircraft in flight and the ground, and the use of wire facilities which the Bell System is in position to supply, make available the proper combination of radio and wires to meet the varied communication requirements of the aviation industry.

Toll-Line Signalling

By R. S. WILBUR
Systems Development Department

SIGNALLING between switchboards at each end of toll lines is necessary so that the attention of the distant operator can be attracted when a call is to be set up and so that a signal to take down the connection may be received when the call is completed. As toll circuits in the Bell System were used at first for transmitting nothing but telephone conversations and their supervisory signals, there were no strict limitations as to the type of signalling that could be used. Twenty-cycle current is used for ringing the bells of local subscribers and it was convenient, therefore, to use the same source of power for toll-line signalling because the toll-line operators had not only to signal the distant operator, but to call the local subscriber after the call had been established.

Conditions soon changed, however. Since long toll lines are expensive, it is desirable to make the maximum possible use of each pair of wires. Toll circuits were rapidly equipped, therefore, so that simultaneous telephone and telegraph messages could be sent over the same circuit. In addition the usefulness of each pair of wires has recently been increased by the use of carrier currents for transmitting many telephone and telegraph messages over a single pair of wires at the same time. The length of circuit over which messages are successfully transmitted has also been greatly increased by the use of telephone repeaters. As the equipment that has been associated with the line to obtain these additional facilities and the increased range, however, will not transmit twenty-cycle current,

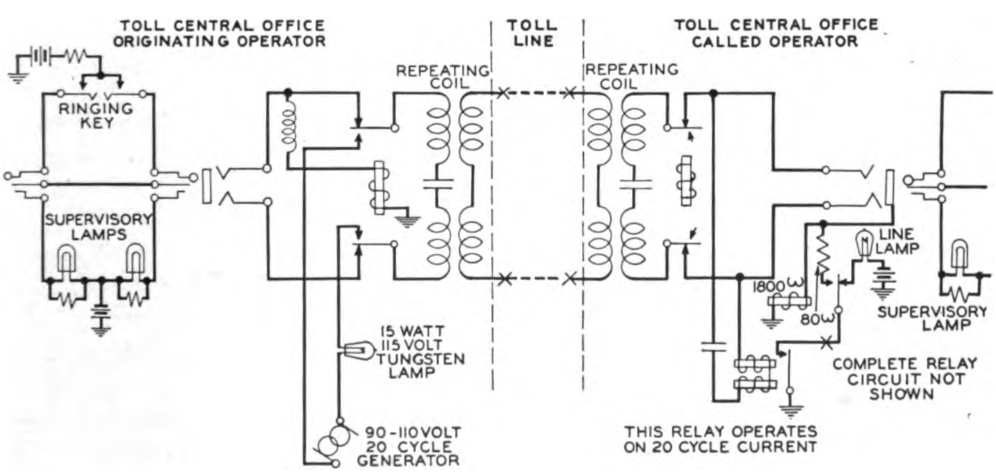


Fig. 1—Toll lines without composite sets or repeaters use twenty cycles for signalling

changes had to be made in the methods of toll-line signalling.

To send a twenty-cycle signal over a toll line used for transmitting only telephone conversations, the operator inserts one plug of a cord circuit

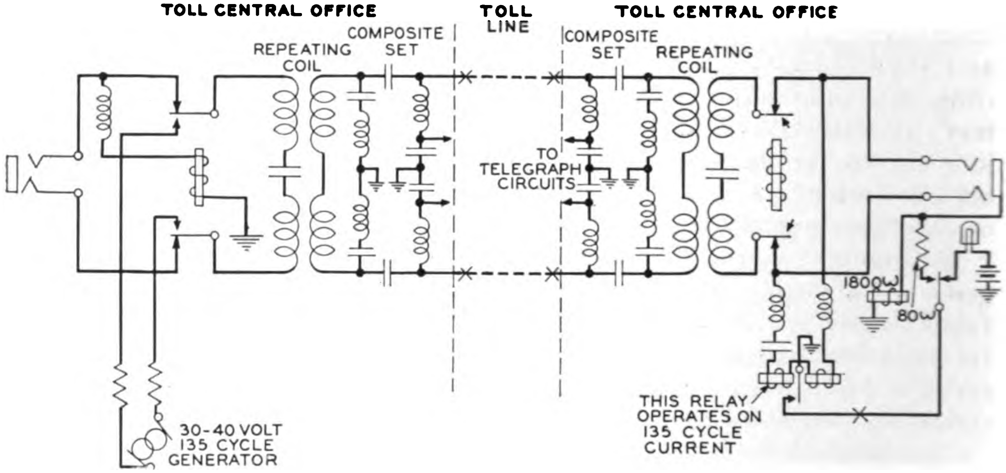


Fig. 2—The use of a composite set makes it desirable to select a frequency for signalling that belongs neither to the telegraph nor the voice range

into the jack of the line and operates the ringing key. This connects twenty-cycle current to the toll line and causes a relay in the distant office to operate, lighting a "line" lamp in front of the operator. The line lamp is extinguished when the called operator inserts the plug of a cord circuit into the line jack. After a connection is completed between the toll line and a subscriber, signals from either office are received at the other on a supervisory lamp associated with the cord circuit.

Means for sending and receiving telephone and telegraph messages simultaneously are provided by the composite set, which separates the voice and telegraph currents at the terminals of the line. A high series impedance and a low shunt impedance, for currents with a frequency of the order of twenty cycles, is introduced by the composite set, which makes it impossible to signal over even a very short line with current of this frequency.

Telegraph receiving equipment is adjusted to operate on currents with frequencies of about fifteen cycles while the lower frequencies transmitted by the voice are of the order of two hundred cycles. A frequency of 135 cycles, about half way between telegraph and voice, was chosen for signalling in order to avoid interference with the telegraph equipment by the signalling current, or with the signalling circuit by the voice current.

Although twenty cycles is suitable for signalling over toll lines not containing composite sets, and 135 cycles for composited toll lines, neither is entirely satisfactory for use on lines using a number of repeaters. Repeaters will not transmit twenty-cycle current, and the gain through the repeater at 135 cycles is approximately six db less than that obtained for the voice currents. In spite of this fact these frequencies were used for signalling when telephone repeaters first

came into use, by relaying the signalling current at each repeater station when necessary. This is accomplished by receiving the signal current in a circuit similar to the terminal equipment in the central office and sending out new twenty- or 135-cycle current at each relay station. As the length of circuits increased, however, and more telephone repeaters were connected into the circuit, the time intervals required to relay the signalling current at each repeater point became prohibitive, and new methods of signalling had to be developed.

Telephone repeatered circuits are generally arranged to transmit satisfactorily voice currents which have frequencies between 200 and 3000 cycles. To signal from terminal to terminal of lines which have several telephone repeaters operating in tandem, the frequency of the signalling current must be within this band of frequencies if the use of relaying equipment at intermediate points is to be avoided. In order to use any of these frequencies, however, the equipment in the receiving circuit, which is connected across the line, must be of a high impedance to avoid excessive transmission losses to voice currents having frequencies in the neighborhood of the signalling frequency. The receiving equipment must be designed also so that it will not falsely operate on voice currents having the same frequency as the signalling current.

One thousand cycles, about the middle of the voice range, has been selected as suitable for signalling, and Figure 3 shows a simplified circuit of the sending and receiving equipment that is used.

The signalling current for this system is obtained from a generator which is designed to furnish 1000 cycles modulated at a twenty-cycle rate. The receiving circuit amplifies the modulated current received from the line and demodulates it to operate a twenty-cycle relay in the plate circuit of a rectifier tube. The transmission loss to voice currents is negligible as the impedance of the input circuit connected across the line is about 20,000 ohms.

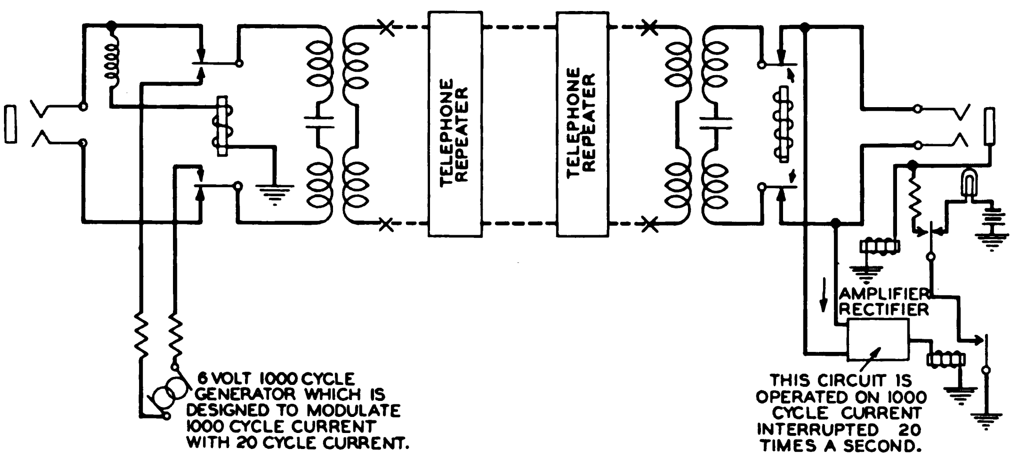


Fig. 3—Telephone repeaters pass only the frequencies of the voice range so that on repeatered lines one thousand cycles is desirable for signalling

False operations of the ringer on voice currents, line noises, or the tones used in the plant for transmit-

ting various traffic indications are practically eliminated by a scheme of double tuning. The input circuit is sharply tuned to 1000 cycles so that only frequencies closely approximating this enter, and after the demodulation there is a second circuit sharply tuned to twenty cycles. As a result only approximately one thousand cycles, modulated at about a twenty-cycle rate, will operate the signalling relays. A further precaution is taken by introducing a time element, so that the current flow must last for a definite time to actuate the signal relays.

The signalling range of this circuit is satisfactory over any toll line which has a transmission equivalent of 20 db or less. Sending current is limited to .001 ampere to prevent objectionable noise in adjacent circuits.

This method is being used extensively in the Bell System for signalling over cable and open-wire circuits of length greater than about 100 or 150 miles. Among such circuits are the New York-Chicago, Chicago-San Francisco, and New York-Havana.

Rights to Subscribe for Debentures

Stockholders of the American Telephone and Telegraph Company have received warrants entitling them to subscribe at par for one \$100 *bond of that company for each six shares of stock held by them on May* 10, 1929. *These bonds pay* 4½ *per cent interest. They may be converted after January* 1, 1930, *into common stock of the company. Between that date and January* 1, 1931, *each* \$100 *of bonds entitles the holder to receive one share of stock on surrender of the bond and payment of* \$80 *in cash. During* 1931 *and* 1932, *the cash payment is* \$90; *in the years from* 1933 *to* 1937, *inclusive, it is* \$100. *The bonds will be paid at their face value on July* 1, 1939.

Rights must be exercised on or before July 1 *next, otherwise they become valueless. The Financial Department of Bell Telephone Laboratories will be glad to give information, and to assist in the purchase and sale of rights.*

Panel Fundamental Circuit

By R. E. COLLIS
Systems Development Department

AMONG the many suggestive words and phrases which have been adopted into the language of the telephone engineer, none, perhaps is more significant than the phrase "fundamental circuit" as used in the panel type of the dial system. As may be inferred from the phrase itself, the circuit thus designated is vitally related to the mechanical and electrical design of the system; it is the signalling circuit by which the sender controls the movement of the selectors which make the various connections required to obtain the number called. The "fundamental circuit" is thus a pulsing circuit, but its method of pulsing, known as the revertive, is decidedly different from the better known direct method.

Both direct and revertive methods of pulsing have their field of practical application governed primarily by the means employed for moving the registers or selectors. The direct method is used in connection with magnetically driven apparatus; apparatus which moves one step and then stops for each pulse received. A subscriber's dialing circuit, illustrated in Figure 1, is of this type. Here the pulses are originated by the opening and closing of the dial contacts at a subscriber's station. The pulses release and reoperate the "L" relay in the sender at the central office, which in turn closes and opens the back contact of the relay and causes a series of register relays to operate. The end of a train of pulses is indicated by a closure of the circuit longer than that between pulses. This long closure allows slow-operating apparatus to function, which transfers the back contact of the "L" relay to another series of register relays.

In contrast with the direct, the revertive method of pulsing is used with power-driven selectors; selectors which, when set in motion at the beginning of a selection, continue in motion until the selection has been completed. With the revertive method, each selector while in motion sends pulses to the sending end where they are registered and acted upon to stop the selector at the required position, while with the direct method the selector receives pulses from the sending end, each pulse moving it one step.

In the panel system the power drive consists of a continuously rotating roll with a cork covering to which the selector elevators are connected by friction clutches operated magnetically during the process of selection. Figure 2 shows the elements of the panel fundamental circuit in conjunction with a power driven elevator of the selector. It will be assumed that the number called requires that the elevator of the incoming selector circuit be raised to occupy position No. 2 of the several possible positions shown in the figure.

When the sender, located in the

calling subscriber's central office, has recorded the number dialed, it prepares the circuit to the counting relays and closes the STP relay to the trunk or fundamental circuit. Relays L and STP then operate in series, the former operating the clutch magnet which forces the rack against the cork roll by means of the bronze roller on the armature of the magnet. This causes the selector elevator to move upward. Meanwhile, since the STP relay has operated, counting relay No. 2 operates.

The elevator, moving upward, brings the commutator brush into contact with segment No. 0 of the commutator, thus closing ground to the tip side of the trunk. Since the ring side of the trunk is already grounded, the tip and ring are short-circuited, and STP releases. This is a signal

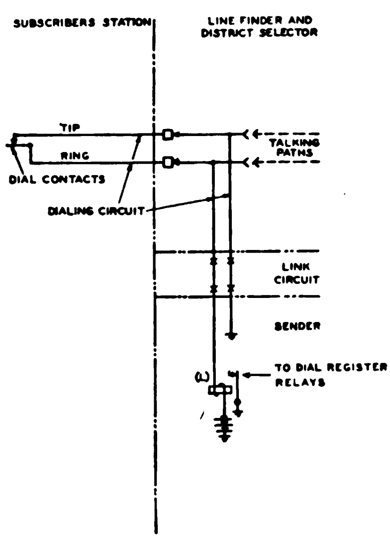


Fig. 1—*With the direct method, pulses are originated at the sending end and operate some form of register at the receiving end of the circuit*

to the sender, informing it that the elevator has reached segment No. 0. The sender records this signal by the operation of counting relay 2′ from ground on the front contact of relay 2. This transfers the lead from the front contact of STP to the winding of the No. 1 counting relay through the back contact on 1′. The L relay in the selector circuit is held operated during this time from ground on the No. 0 commutator segment.

The advance of the elevator now causes the commutator brush to break contact with the No. 0 segment, reestablishing current in the fundamental circuit and operating STP which, in turn, operates counting relay 1.

The elevator next makes and breaks contact with No. 1 commutator segment. This releases and reoperates the STP relay, which is a signal to the sender that the commutator has reached position No. 1. The sender records this fact by the operation of relays 1′ and 0.

When the commutator brush makes contact with segment No. 2 of the commutator, relay STP releases again, this time allowing relay BO to operate, which opens the fundamental circuit. Relay L is, as before, held operated by the ground on the commutator segment so that the elevator continues to advance until the brush breaks contact with segment No. 2. When this occurs relay L releases, disengaging the clutch, and stopping the upward movement of the elevator which is prevented from dropping back by a pawl dropping into a slot in the rack.

One important requirement of the fundamental circuit is fast operation. Time required to set up a connection not only delays the subscriber but limits the traffic which a given amount

of equipment can handle. It is therefore essential that the speed of all the apparatus be as fast as is possible, consistent with reliable operation. The maximum speed of pulsing of the revertive circuit is approximately thirty-two pulses per second. To follow this speed properly the STP relay and the counting relays are designed for fast operation. The latter, of the No. 208 type, are especially fast; in fact they are among the fastest in the telephone system.*

The STP relay must function over trunk circuits of various lengths and resistances, which means that its operating and releasing times are subject to considerable variation due to the varying capacity and resistance of the loop. The relay which has been found to meet best the exacting requirements of these conditions is one of the No. 207 type.

The design of the L relay at the receiving end of the fundamental circuit is also of great importance because its inductance and resistance affect decidedly the operation of the STP relay, and also because its releasing time affects the stopping of the selector at the required position. When the commutator brush breaks contact with a segment, the current flowing in the winding of L is suddenly reduced from that determined by the resistance of the relay alone, to that determined by the resistance of the trunk circuit including the STP relay. This energy, stored in the winding of the L relay, discharges through the trunk circuit, and is very effective in securing fast operation of the STP relay.

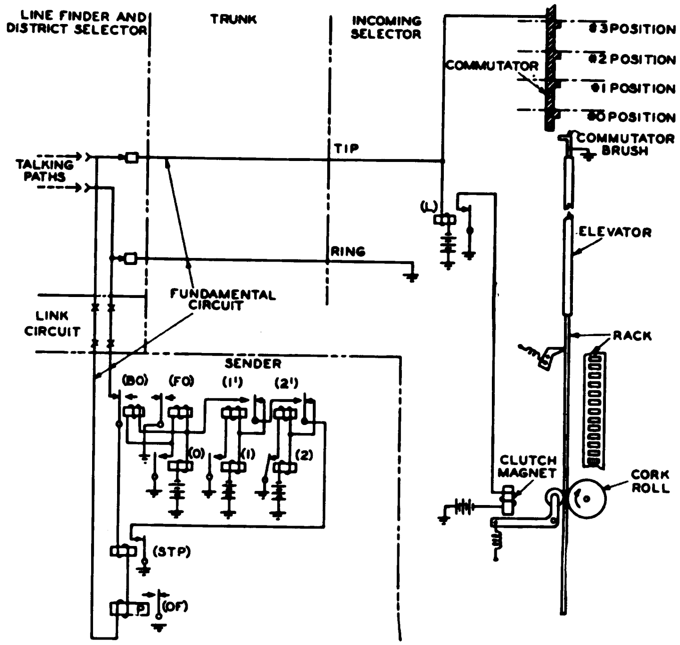


Fig. 2—With the revertive method, pulses are originated at the receiving end and actuate registers or relays at the sending end of the circuit

At the end of the selection—when the fundamental circuit has been opened at the BO relay and the commutator brush breaks contact with the segment—the L relay must release quickly to prevent overstepping of the elevator. When selections are being made over short trunk loops, L releases practically on open circuit, which insures a quick release. As the length of the trunk loop is increased, however, the mutual and grounded capacity of the cable act to cause the L relay to be slow in releasing. A length of cable is finally reached which causes the L relay to

* *Critical Relays of the Telephone System.* Bell Laboratories Record, *October,* 1928, *p.* 51.

release so slowly that, with the simple circuit arrangement shown in Figure 2, there is danger of the elevator overstepping.

One of the methods employed to overcome this condition is shown in Figure 3. Here the L relay controls directly, not the clutch magnet, but one winding of an auxiliary relay T which in turn controls the clutch. A secondary winding on the T relay is connected to an auxiliary "centering" commutator whose segments also are grounded by a brush as the elevator advances. Due to the position of the segments of the pulsing commutator

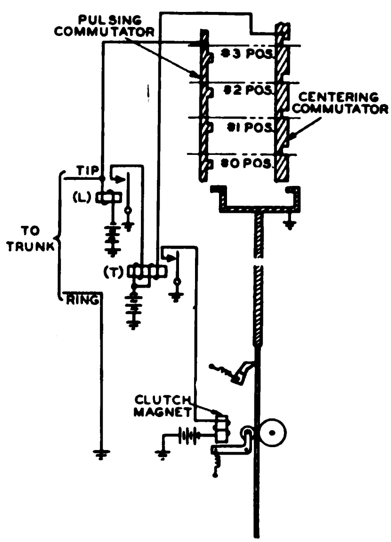


Fig. 3—To avoid the effect of long loops on the action of the L relay, a second relay has recently been employed to control the action of the clutch

relative to those of the centering commutator the ground pulses are transmitted earlier relative to the stopping positions, than when only a single commutator is used. When relay L releases after the last pulse, relay T is still held operated over its secondary winding to commutator C, until the proper position is reached. The releasing time of the T relay can be made very small regardless of the length of the cable loop, and relay L may be allowed to release as slowly as necessary, the only requirement being that it be released by the time the brush of the centering commutator leaves the segment.

Although the auxiliary relay arrangement just described is used in the latest type of panel selector circuits, full advantage can not always be taken of the centering commutator arrangement because of limited space on the commutator bar. For this reason a fast-releasing L relay is still essential. The type which best meets this condition and at the same time furnishes a high inductive "kick" for the STP relay is the N type relay. Since this relay is rather expensive a method has been devised to use the L relay of one circuit to control the positioning of two selectors, such as the incoming and the final.

This arrangement is shown in Figure 4, which represents the fundamental circuit of the latest type of panel incoming and final selectors when in position for final selections. With this arrangement the relay designated C in the final circuit performs the same function for the final selector that is performed by the T relay for the incoming circuit shown in Figure 3. The L relay acts as a line relay for both incoming and final selectors.

Besides those for controlling selections, the panel fundamental circuit must also transmit signals for other purposes. After the elevator of the incoming selector has been raised to the proper position in the selector bank, it finds itself at the lowest terminal of a group, any of which except

the last may be used to complete the connection. Some of these terminals, however, may already be in use by other selectors. It is therefore necessary for the incoming selector to pick out for itself an idle terminal from among those available in this particular group. This process, called "trunk hunting," has already been described in BELL LABORATORIES RECORD.*

If all of the trunks in the group are already busy the elevator of the incoming selector will come to rest on the last terminal of the group, called the "overflow" terminal. In such an event the incoming selector signals the sender that the "overflow" condition exists by returning "reverse battery," that is, the condition of battery on the tip, and ground on the ring is reversed. The OF relay in the sender, Figure 2, which is in the fundamental circuit during all selections, is a polarized relay and is so poled in the circuit that it operates only when a reverse battery condition exists. When the OF relay operates, the sender, if selections have not been completed, recognizes that overflow condition exists and immediately causes the district selector circuit to return the distinctive "overflow" tone to the calling subscriber, which is equivalent to "all trunks busy" of the manual operator.

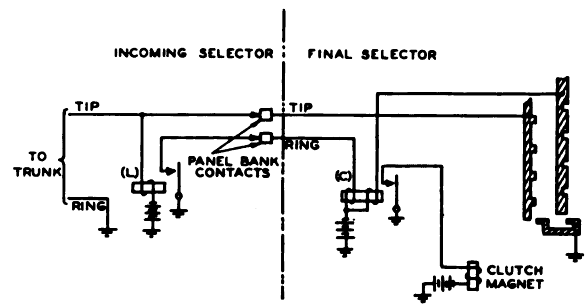


Fig. 4—A recent development uses only one L relay for both the incoming and final selectors

After the sender has completed final selections, it awaits the signal from the incoming circuit that both it and the final circuit are ready for the talking connection to be established. The incoming selector produces this signal also by returning reverse battery to the sender. The sender, since final selections have been completed, does not interpret this signal as an "overflow" but proceeds to cause the district selector to cut through the talking circuit. Having finished its task, the sender frees itself from this call and awaits another call.

* *September*, 1928, *p.* 5.

All-Relay Register Circuit

By R. RAYMOND
Systems Development Department

IN dial systems connection with a subscriber is obtained by a series of selections, and the manner in which this selection is controlled is one of the features that distinguish the panel from the step-by-step method. With the latter the selection directly follows the dialing; the first digit dialed causes the first selection; the second, the second selection; and so on. In the panel system, on the other hand, the complete number is recorded in the sender which subsequently controls the selection according to the number registered in it. As an inherent part of the sender there is thus a register circuit.

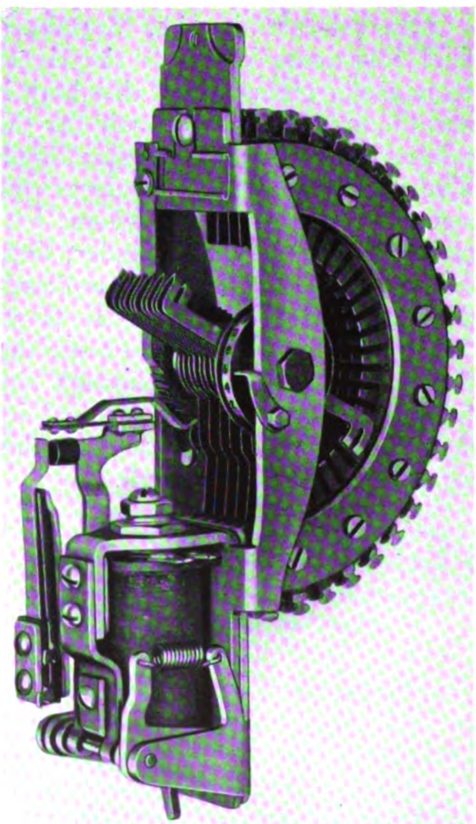


Fig. 1—The 200-type selector was used for recording the digits dialed with the early senders

Formerly rotating switches, known as 200-type selectors, were used for this purpose. One of them responded to each dialing operation—moving around in step with the dial to a terminal corresponding to the digit selected. When the decoder* sender was developed, however, a new register circuit consisting entirely of relays was incorporated in it. By this change less space is required, and certain operating improvements are made. Maintenance is simplified and greater variation in the action of the subscriber's dial is possible without causing trouble.

The "all-relay register circuit," as the new development is called, consists of two sets of relays; one set counts the impulses of each dialing operation, and the other records each of the seven or eight digits of the number dialed. The position of these relays in the sender cabinet is shown in Figure 2. In the lower right hand corner are six pairs of counting relays which are explained later; and at the left are eight rows of registering relays. When a digit is dialed the

* Bell Laboratories Record, *Vol. VI, No. 3, pp. 273-277, May, 1928.*

relays of the first set count the number of impulses, and when the dial has returned to the normal position, the number counted is registered by the relays of the second set. The first group of relays is then returned to normal position, where it is ready to count the impulses of the second dialing operation.

The set of counting relays consists of twelve relays arranged in two rows of six each; and working with them is a group of six auxiliary relays. These are all shown in Figure 3. In the extreme upper right hand corner is indicated the dial contact of the subscriber's set which is closed at all times except for the duration of the individual pulses as the dial returns to normal after having been pulled around. Thus, the line relay (L) is held operated by the dial contact all the time the receiver is off the hook and the sender is connected to the line, except when the contact is momentarily opened to transmit a pulse.

Operation of the line relay operates relay L1; operation of L1 operates SR; and operation of SR operates SR1—the front or make contact of each relay closing a circuit to energize the next one. When the line relay releases on a dial break, L1 releases also. Relay SR, however, has a heavy block of copper on its core which makes it very sluggish in action, so that it does not release on the momentary dial breaks but remains continuously operated, and consequently SR1 remains operated also. The function of these last two relays is to recognize that the sender is attached to the line and that the receiver is still off the hook. The springs and wiring of the six relays in the top row are not all shown in the diagram as they have special functions and details of operation which do not require any discussion at this time.

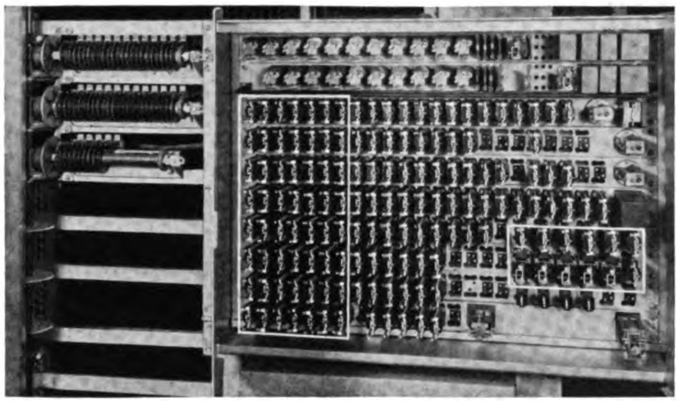


Fig. 2—Eight groups of register relays and the twelve counting relays are indicated on this panel sender

When relays L and L1 release on the first dial break, the register advance relay RA is energized by a circuit through the back or break contact of relay L1. It is a slow release relay like SR, and after being operated by the first dial break, remains operated throughout the subsequent momentary closures and breaks of the dial and is released when the dial contact closes at the end of the set of pulses. Relay RA1 operates in reverse order, releasing while the dial is returning from a pull and remaining operated between dialing operations.

The counting relays proper, occupying the two lower rows of Figure 3, are arranged in pairs numbered P1 and P1′ to P6 and P6′ inclusive. Leading from these relays to the

group of register relays are six leads marked RA, 1, 2, 4, 5, and Z. How these act on the register relays will be described a little later; for the present it is sufficient to know that a ground on any of the numbered leads — 1, 2, 4, and 5 — indicates that that number has been dialed. A ground on two of them such as 1 and 2 indicates that 3 has been dialed, or a ground on 1, 2, and 5 indicates that 8 has been dialed. A ground on Z indicates that 0, the last digit, has been dialed. At the end of each dialing operation a ground is placed on lead RA which locks up the number dialed with the preceding operation, and brings into action another set of register relays to record the next digit dialed.

Relay RA1 releases at the first open of the dial contact and, due to slow release feature of RA, remains released during the subsequent makes and breaks of the dial switch until a short interval after the last make allows RA to release and RA1 to operate. During transmission of the dialing pulses, therefore, a ground is placed on the lead running from the back contact of RA1 to the counting relays. At each opening of the dial contact a ground is momentarily placed, through the back contact of L, to another lead running to counting relays. It is the action of these two grounds, one retained and the other pulsing with the dial, that causes the counting relays to act.

The first momentary ground from L brings in P1 and on the removal of this ground, P1′ is brought in through the ground from RA1. This action continues with successive pulses, bringing in next P2, and P2′, followed by P3 and P3′, P4 and P4′, P5 and P5′, and then starting over again with P1 and P1′ which had remained operated only till P2′ had been closed. Just which relays are operated and which released, at each make or break of the dial contact, is

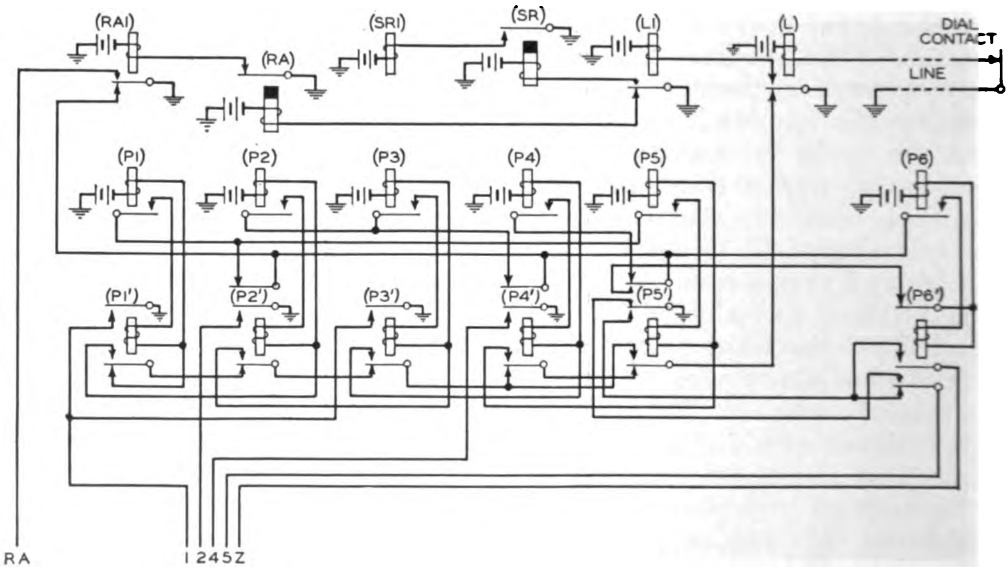


Fig. 3—Counting Relays. Instead of using ten relays to count the number of pulses sent out by the subscriber's dial, only six are used; the five used to count the first five digits also count the last five—the sixth relay being operated to distinguish between 1 and 6, 2 and 7, and so forth

shown on Figure 4. Here, near the top, is represented the line current interrupted the full ten times by the dial contact. Just above, for each make and break, is marked the relays that are operated, and just below, those that are released. It will be held operated a ground exists on lead 2 also, so that both 1 and 2 are grounded which records the number 3 on the register relays. The duration of the grounds on the five leads to the registering relays is shown at the bottom of Figure 4.

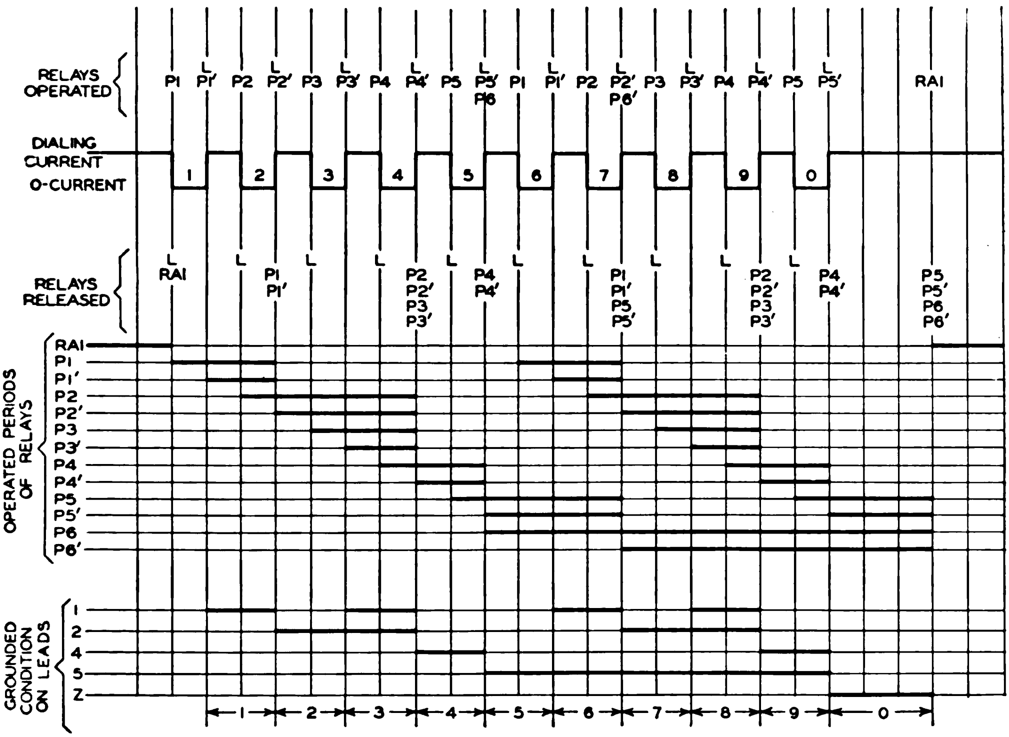


Fig. 4—Operation of the various relays and the length of time they remain operated in relation to the dial pulses are indicated above

noted for example that at each dial opening L is released and at each closing it is operated. Below this is a group of lines—one for each relay—indicating the duration of operation of each.

The completion of the first pulse brings in P1′ and through it places ground on lead 1. The second pulse releases P1′ but brings in P2′ which puts ground on lead 2. The third pulse brings in P3′, placing a ground on lead 1 again, and as P2′ is still

Completion of the fourth pulse operates P4′, placing a ground on lead 4 and releasing relays P2′ and P3′. Completion of the fifth pulse brings in P5′ and through its contacts, and through a contact of P6′ after P5′ has released, ground is left on lead 5 until the end of the tenth pulse. The sixth pulse brings in P1′ again and the counting proceeds as for the first five pulses except that lead 5 is grounded in addition. Completion of the tenth pulse places a ground on

lead Z and removes the ground from all the others. Shortly after the dial has returned to its normal position RA1 is operated which releases all the counting relays that are operated, locks up the number dialed on one of the groups of register relays, and prepares the next group to receive the following digit.

Two of the eight groups of register relays are shown in Figure 5, the other six groups are arranged in the same manner and to form a complete diagram would be drawn in below the groups shown.

After the receiver has been lifted from the hook and the sender has been selected, the C relay of the first are placed on one or more of the five connecting leads to operate corresponding relays in the register group. The relays remain operated as long as ground remains on their leads so that the ones operated for any digit dialed are indicated by the heavy lines on the bottom section of Figure 4.

When the dial has returned to normal, and after the short time required for the slow-release relay RA to release, a ground is placed on the lead RA through the front contact of relay RA1. Lead RA passes through a series of back contacts on the C relays of all register groups but the first, through the winding of the AL relay, to battery through whatever

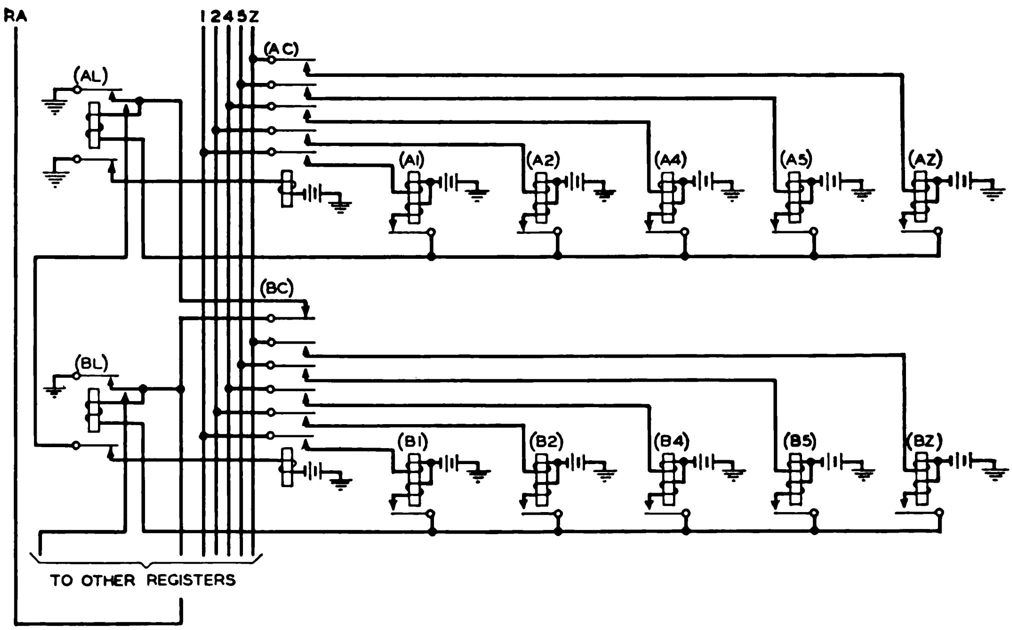


Fig. 5—The register relays are arranged in eight groups—one for each digit dialed

or "A" group (Relay AC) operates and connects the five leads—1, 2, 4, 5, and Z—from the counting relays to the windings of five corresponding relays of the first group of register relays. As the pulses from the first dialing operation come in, grounds relays in the first group are operated. This holds these relays operated and at the same time operates AL. The operation of AL releases AC, thereby disconnecting the first group of register relays from the five counting leads, and, through the back con-

tact of BL, operates BC—connecting relays of the second group to the counting leads. The operation of BC also disconnects lead RA from relay AL which is now held in from a ground through one of its own front contacts.

In a similar manner the second digit dialed is recorded on the second group of register relays, the third digit on the third group, and so on for the complete eight digits. When dialing is completed the number is recorded by the eight groups of register relays, one digit by each group. The additional contacts on these register relays, required to control the selection of the number called, have been omitted for the sake of simplicity.

Silently and with machine-like precision the counting relays count the pulses from each dial operation, and when the dial returns to normal position the register relays, with equal silence and precision, record consecutively the digits dialed. The mechanical movements of the 200-type selectors, formerly used for registering, have been done away with, and smaller, quieter, more easily maintained equipment has been substituted.

A Slide Rule for Vector Calculations

By M. K. KRUGER
Apparatus Development Department

ELECTRICAL networks such as filters, attenuation equalizers, transformers, balancing networks and speech delay circuits are used in large numbers in many parts of the telephone plant. For example, filters separate the voice and carrier frequency currents at the ends of each toll circuit on which carrier currents are superposed, and attenuation equalizers are used on broadcasting circuits to give sufficiently uniform transmission over the wide range of frequencies necessary for high grade radio programs. Transformers are extensively used at junction points in circuits where the impedances are unequal.

These networks are made up of resistances, inductances and capacities and in some cases the number of elements reaches a hundred or more. In order to ascertain their performance accurately, a large amount of mathematical computation is involved. Any considerations simplifying the work of computation are therefore deserving of serious thought, particularly when a considerable saving in time is thereby effected.

In most cases the solution of electrical networks involving alternating voltages can be simplified by expressing the voltages and currents as vectors, to show their magnitudes and the phase relationships between them. The voltages and currents are represented in polar form, with magnitude and direction given, or in rectangular form, by complex numbers giving the real and imaginary components. Partly offsetting the advantages of this notation, however, is the work frequently involved in solving the equations, particularly the routine operations in transferring them between the polar and rectangular forms.

If a complex quantity is expressed in polar form, its length r and the angle θ which it makes with the hori-

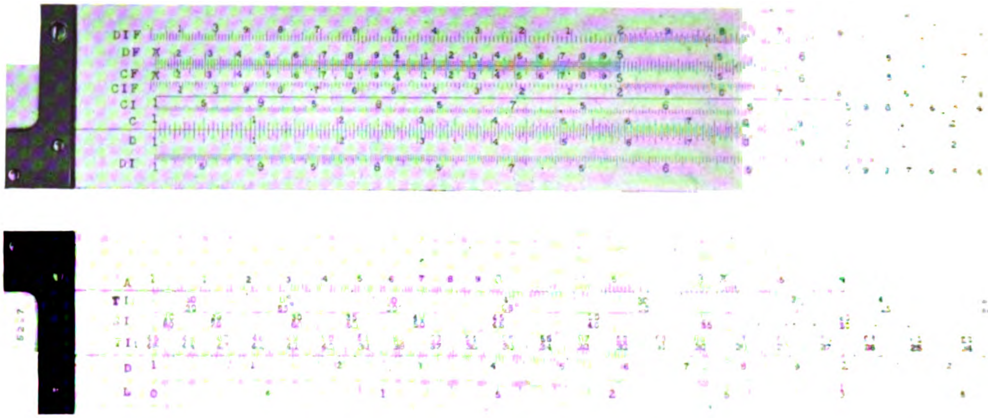


Fig. 1—*Above, the front of the new rule, with the added scales, DIF and DI, on the upper and lower stationary sections; below, reverse side, showing the inverted trigonometric scales on the slide*

zontal axis are given, usually in the notation $r\,\underline{|\theta}$. In the rectangular form the number is expressed as $a + jb$. The relationship between these notations, shown in Figure 2, is such that either can be changed to the other by the simplest trigonometric equations. Simple as it is, however, the change involves a number of separate computations, and when there is an extensive series of equations to be solved the work of computation is long and tedious.

Various mechanical devices, some of them specially designed for the purpose, have been used for reducing the time taken by this operation. An ordinary duplex slide rule is used most commonly, but it was designed for general use rather than for this particular operation, and numerous settings of the rule are required. An instance is that the tangent scale between the values 0.1 and 1.0 runs the full length of the slide, while in the same linear distance the sine scale extends between the values 0.01 and 1.0. Since both sine and tangent of the angle are used in each transformation, the time lost in resetting the rule on account of this discrepancy between the two scales is considerable. Other similar situations require more settings of the rule than are inherently necessary for these transformations.

Accordingly in 1916 F. A. Hubbard* designed a special slide rule for vector transformations, with scales provided on it which reduced to three the number of settings of slide and hair line for a complete transformation. Such a rule was later made, and it proved a valuable time saver. It had however two disadvantages. Although its length was twenty inches, the scales were so arranged that the accuracy was only that of a ten-inch rule. Also it was necessary to set up the numerical factors on an inverted scale, reading from right to left; that increased the chance of error from carelessness on the part of users, since the reverse side of the rule was also used for ordinary operations of multiplication and division.

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* *Now Vice-President and General Manager of the Mexican Telephone and Telegraph Company.*

Another special slide rule, intended particularly for solving equations involving hyperbolic functions, was designed by Professor M. P. Weinbach of the University of Missouri, and was described in the Journal of the A. I. E. E. for May, 1928. Problems involving ordinary complex numbers may be solved as well, but four settings are required for a change from rectangular to polar form, and six settings are needed for the reverse transformation.

To expedite our filter computations, a twenty-inch rule was designed with the scales arranged especially for vector transformations. Preliminary arrangements for its manufacture were made with the Keuffel and Esser Company early in 1928, and in the summer six of the rules were made for the Research Department and the Apparatus Development Department. In this rule only one setting of the slide and two settings of the hair line are needed in changing a complex number from either form to the other. The numbers are set on an ordinary logarithmic or D scale, and the operations are performed in the same manner as are multiplication or division on an ordinary slide rule. The results are obtained on the D scale — the full-length logarithmic scale on the stationary part of the rule — and since the rule is of duplex type, additional operations such as multiplication or division may when desired be carried on without a resetting of the complex number.

The front of the rule, shown in Figure 1, has the scales usual for polyphase duplex rules, and has in addition the reciprocal or inverted scales DIF and DI on the stationary part of the rule. These scales, giving the reciprocal of a result directly, end the need for a separate operation to secure a reciprocal. They are specially useful in such operations as finding capacitive reactance and admittance. For obtaining the reactances in a network containing both inductance and capacity only a single setting of the slide is made, and then all the reactances are obtained by moving the hair line.

It is on the reverse side of the slide that the principal changes have been made. Trigonometric scales for sine and tangent have both been inverted, and are both referred to the DI scale — the inverted D scale — rather than to the A and D scales, respectively, as before. Referring both to the same scale does away with the

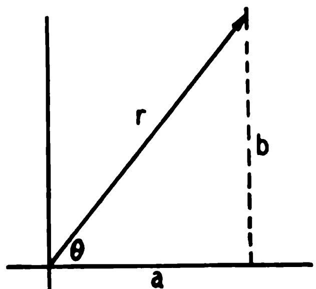


Fig. 2—In a complex number, r *is the vector and θ the angle it makes with the axis of real numbers;* a *is the real component and* jb *the imaginary component. With either* a *and* b *or* r *and* θ *known, conversion between polar and rectangular form consists in finding the other pair of values*

need for resetting the rule to use one function when the other has just been ascertained. The principal tangent scale TI_1, runs from 5°43′, the angle whose tangent is 0.1, to 45°, just as in all polyphase rules, and in addition an auxiliary tangent scale TI_2 running from approximately 34′ to 5° 43′ is given, to cover the angles whose tangents are between 0.01 and 0.1.



Fig. 3—Beginning of a conversion from rectangular to polar coordinates. When the slide is set on 1195 *and the hair line on* 1530 *on scale D, angle* θ *is given as* 52° *on scale* TI_1. *The later example is also illustrated here. With the slide set on* 119.5 *and the hair line on* 1530, *the angle is read on scale* TI_2—85° 32′

The sine scale extends between the limits 0.1 and 1.0 only—that is, between angles 5° 45′ and 90°. For angles less than 5° 45′ however sine and tangent are so close together that scale TI_2 may be used in place of an auxiliary sine scale without serious error.

Convenience of this rule in changing a complex number from rectangular to polar form can best be shown by a numerical example, such as 1195 +j1530. First the angle θ is obtained through its tangent. The index of the slide is set on the smaller number, 1195, on the D scale, and the hair line is moved to the larger number, 1530, on the same scale. Then the point on the slide beneath the hair line marks the ratio of the two sides, which is the tangent or cotangent of the angle, depending on which side was larger; in this case the ratio is the tangent. Then the point on the tangent scale beneath the hair line is read directly as the angle wanted—in this case, 52°. With the angle known, the length of the vector is next obtained by dividing the length of the vertical component by the sine of the angle, or the horizontal component by the cosine of the angle. In this case the horizontal side, 1195, is already set on the rule; accordingly the hair line is moved to 52° on the divisions of the sine scale SI corresponding to cosine values, and the length of the vector, 1942, is then found under the hair line on scale D.

In the example given, the ratio of the larger to the smaller component was less than 10, and the tangent scale TI_1 was therefore used. When the ratio is between 10 and 100 the

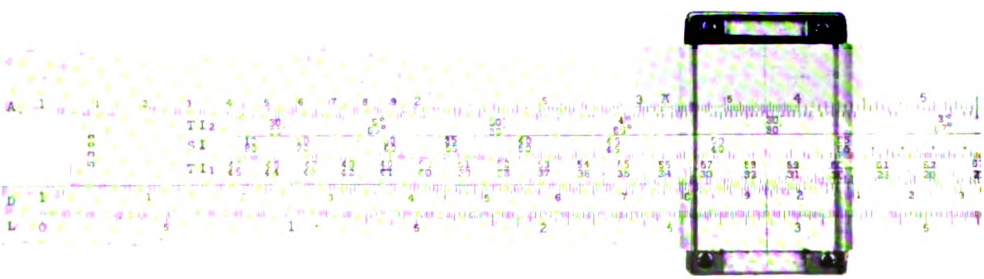


Fig. 4—With θ *learned, the slide is left at* 1195 *and the hair line moved to* 52° *on scale SI. Then the vector* r *is given on scale D; its value is* 1942

procedure is the same except that the other tangent scale on the slide, TI_2, is used. It gives the tangents of angles between 85°43′ and 89°26′, and of course the cotangents of the complementary angles. A case in which this scale would be used is the complex number 119.5 + j1530. The index of the slide is set on stationary scale D at the smaller number, 119.5, just as before and the hair line moved on the same scale to the larger number, 1530. Then the ratio of the two sides appears on the slide, and on scale TI_2 it represents the tangent of angle θ — in this case, 85°32′.

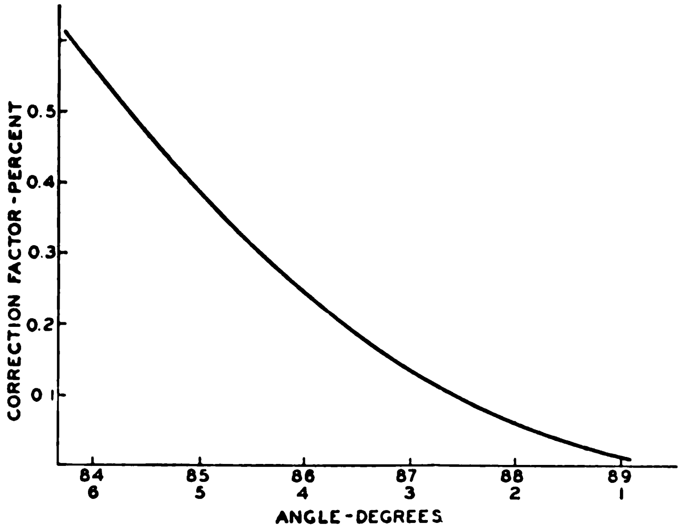


Fig. 5—For values of θ not given on scale SI, the larger component is increased in accordance with this curve to get the vector

The length of the vector cannot be obtained directly on the rule, since the sine scale has not been continued between 0.01 and 0.1 on a scale comparable to TI_1. Should the vector be wanted closely it can be obtained readily by auxiliary computation, but ordinarily it is sufficiently accurate to take the larger component as the value of the vector. At most the error is one-half of one per cent, when the ratio of the components is just ten, and as the ratio increases the error drops rapidly, so that when the larger side is about twenty-two times the smaller, the error is only a tenth of one per cent. The factor by which the larger component is to be increased is shown in Figure 5; when the desired accuracy justifies the extra computation, the larger component is increased by the fractional per cent through additional settings of the rule or by mental calculation. In the example shown, the increase is 0.3%, and length of the vector 1535.

When a complex number in polar form, as 1942 $\underline{|52°}$, is to be changed to rectangular form, the operations are the reverse of those already described. The hair line is set on the length of the vector, 1942, on scale D; the angle 52°, on sine scale SI is drawn beneath the hair line; then the hair line is moved to 52° on tangent scale TI_1. Thereupon the two components are read directly on scale D — one of them beneath the index of the slide, and the other at the hair line. That at the index, 1195, is the vector multiplied by the cosine of angle θ and is accordingly the real component; the number at the hair line, 1530, is the imaginary component — the vector multiplied by the cosine of the angle and then multiplied by the tangent.

Although the rule was originally

intended primarily for filter computations, its usefulness is not restricted to those engaged in designing filters. In ten-inch size it would be in many ways advantageous for general engineering and student use. For such a field however, certain modifications would be desirable. On the tangent and sine scales the angles should be divided decimally rather than in minutes and seconds, to facilitate interpolation and to simplify addition and subtraction of angles. The scale of equal divisions, or L scale, might well be placed on the front of the rule, and the space on the reverse side vacated by this change used for exponential, or log-log, scales. With that arrangement there would be no need for a cube or K scale, and little if any need for a square—A—scale. Another change, though one whose general advisability is somewhat open to question, is a further modification of the sine scale. That part of the scale between 0.707 and 1.0, or between 45° and 90°, is never used in transforming complex numbers, and its only value is to give directly the numerical values of sines and cosines within its range. Since these could easily be found from other parts of the sine scale by additional operations, this part of the SI scale could be replaced by an SI_2 scale extending from 5° 45′ down to 4°8′. If that were done, the angle whose vector could be obtained directly on the rule would be increased from that with the tangent 10 to that with the tangent 14, and the greatest error which would be present if the vector were not corrected in accordance with the curve of Figure 5 would be 0.3% rather than 0.5%.

Since complex numbers enter into computations in many other fields than those of telephone filters, a rule so made would speed up computations of many sorts, and at the same time fit the general types of computation for which a slide rule is commonly used.

The Inquiring Investor

Question—American Telephone stock is selling at its highest price in history. Is this the time to accept a very substantial profit?

Answer—You have in your American Telephone stock an interest in a huge company which has reported a steady expansion of earning power. While the common dividend yields slightly less than 4% at the current price of 220, the periodical rights materially increase the return. As a permanent investment the stock has few if any peers.

—*Barron's, May* 13, 1929.

Condensers for Many Uses

By C. R. YOUNG
Apparatus Development Department

STRIPPED to its essentials a condenser consists of two plates or sheets of conducting material separated by a dielectric or non-conducting medium. The Leyden jar, a glass container coated inside and out with tinfoil, was one of the earliest types used. With the growth of the electrical industry, and particularly with the use of radio broadcasting, condensers have come to be commonplace pieces of equipment. Modern communication circuits, in particular, would be impossible without them. Ranging in capacitance (in the non-adjustable types) from twelve hundred-thousandths to twelve hundred microfarads, a range of over ten million to one, they are used in almost every telephone circuit.

When an electromotive force is connected across the inner and outer conducting surfaces of a condenser, a certain amount of electricity is stored which is discharged when the two surfaces are later connected together. As there is no electrical connection between its two metallic surfaces, a condenser constitutes an "open circuit" in any steady current network in which it is placed. Due to its ability to store a charge directly proportional to the voltage across it, however, the condenser acts as though it were conducting whenever alternating or varying potentials are applied to it. With an alternating potential, for example, as the voltage increases the condenser charges and as the voltage decreases it discharges so that there is a continuous flow of current to and from the condenser which follows the variations in the potential.

This ability of the condenser to transmit alternating or varying currents and to block direct currents makes it very useful in telephone circuits. A condenser is used in every subscriber's set primarily to pass the alternating ringing current to the bell and to keep from it the direct current from the central office battery. This use of the condenser is plainly evident in Figure 1 which shows the new sub-

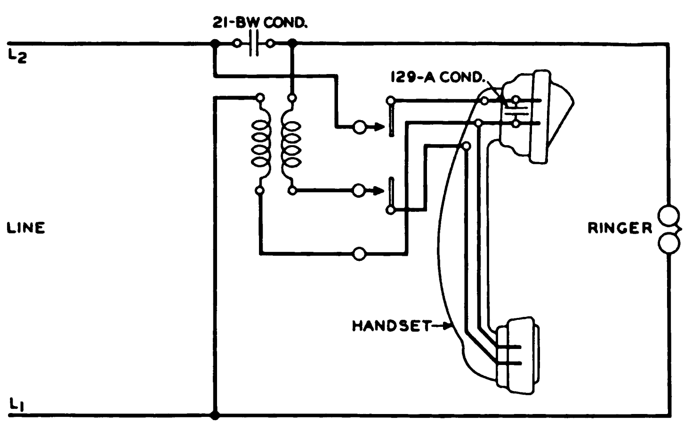


Fig. 1—Diagram of subscriber's set showing a condenser across the transmitter of a hand set as well as in the ringing circuit

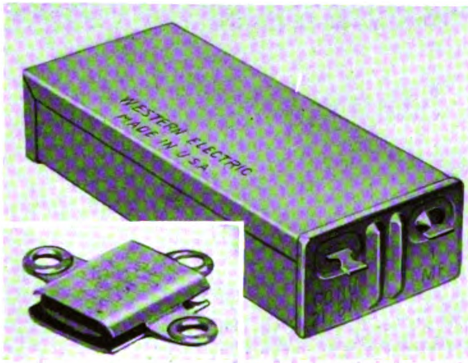


Fig. 2—21-*BW condensers are used in the ringing circuit of all common battery subscribers' sets. Fig.* 3—(*Inset*) *The* 129-*A condenser used with the new hand sets is one of the smallest used in the telephone system*

scriber's handset. A second condenser, the 129-A, is bridged across the terminals of the transmitter to prevent the granular carbon from cohering.

Condensers for most of these common uses in the telephone plant have tinfoil, only a few ten-thousandths of an inch thick, for the conducting surfaces, and paper for the dialectric. Two long strips of tinfoil separated by two or more sheets of very thin paper are rolled up, compressed to a roughly rectangular shape, impregnated with wax and then, surrounded by a sealing compound, are placed in a suitable metal casing. When five mil treated paper with a width of four inches is used, about eighteen feet is required for each microfarad of capacity. At present condensers of this type are being manufactured by the Western Electric Company for the Bell System at the rate of about seven million microfarads per year. They range in capacitance from twelve hundred-thousandths to two microfarads.

Of last year's production some 1,200,000 microfarads were made into the 21-BW condensers, shown in Figure 2, which are used in the common battery subscribers stations. Some three thousand microfarads, assembled in units of about one hundredth of a microfarad capacity and known as the 129-A condenser, shown in Figure 3, were used with handset transmitters. A large part of the remaining production appeared as the numbers 57, 89 and 90 condensers, shown as Figure 4, which are arranged to mount on relay racks in central offices where they serve various purposes.

In contrast with the small No. 129-A, and two hundred thousand times larger, is the 20,000 volt condenser used in the filter power circuit at the 3XN radio transmitting

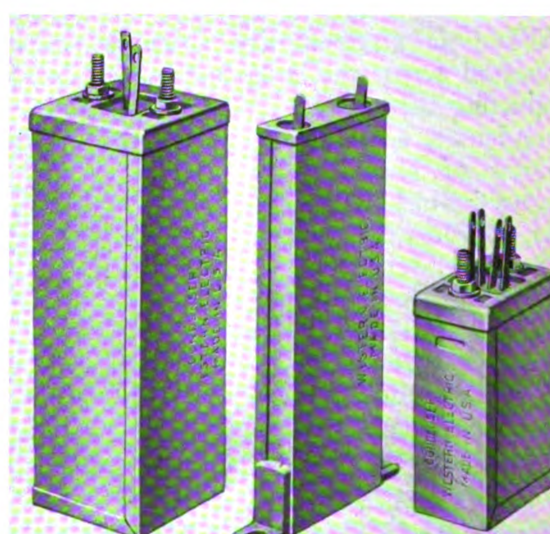


Fig. 4—*Condensers for mounting on relay racks are made in many shapes and sizes*

station at Whippany. These, shown as Figure 5, are also built up of tin-foil and paper with five layers of thin paper between the strips of foil and the whole carefully treated and potted to prevent the entrance of moisture. By connecting all the units in parallel a total capacitance of three micro-farads is obtained.

Paper condensers have the advantage of being inexpensive, but there are certain limits to the accuracy with which they can be commercially produced. Ordinarily a tolerance of plus twenty-five percent is allowed and in the places where they are used this amount of divergence from their nominal capacitance is permissible. By selection after manufacture, smaller divergences from the nominal capacitances may be obtained. There are situations, however, where very high accuracy is required. Filters used with carrier systems are among them. For many such uses the allowable variation, even including aging over a period of fifteen years, and temperature changes that occur in a central office, is about one percent.

To obtain this high accuracy a different type of construction is employed. Mica is used for the dielectric and, instead of being rolled, alternate layers of conductor and dielectric are laid one on top of the other. Alternate sheets of foil extend beyond the dielectric on opposite sides and when the stack is completed the sheets on each side are connected together. This method, in addition to giving greater uniformity in capacitance, gives very low resistance for the conducting path. With the paper condensers used with subscribers' sets a single conducting lead is laid across the strip before it is rolled up so that the average path for the current is much longer.

Although the layer method of construction gives a fairly high degree of accuracy in itself, even a greater degree is made possible when necessary by making some of the conducting foils of brass, to obtain greater

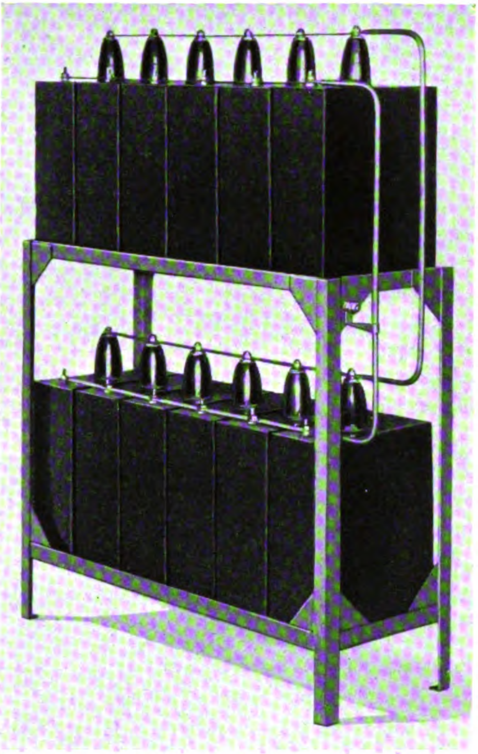


Fig. 5—Twenty-thousand-volt condensers used at the Whippany station

strength, and then after the condenser is tested, the exact capacitance required is obtained by pulling a few of these foils partly out from the pack. Two of such dry stacked mica condensers are shown as Figure 6.

Besides paper or mica as the dielectric material, air is sometimes used—particular for the lower voltages and smaller capacities. One of the principal uses of air condensers is for radio receivers but they are also

used in the impedance bridge described in Bell Laboratories Record* for December, 1928. One of the advantages of the air condenser is that it is readily made adjustable.

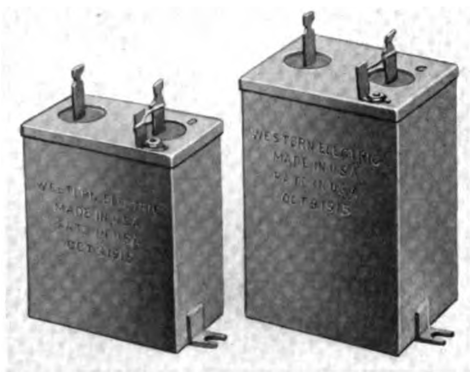


Fig. 6—Typical mica condensers of high accuracy and constancy. The containers are now finished with aluminum lacquer

The plates comprising it are so mounted that one set of alternate plates is fixed and the other set can be rotated about a perpendicular axis. This arrangement allows the effective area and hence the capacitance, to be easily changed. At the other extreme, where very large capacitances are required, and where phase angle and high voltage are not important, the electrolytic* condenser is used. Capacitances obtained for a given volume are enormously greater than could be obtained with mica, paper, or air condensers.

The uses to which condensers are put in the Bell System have increased at a rapid rate during the last ten years, due to advances in wire and cable systems, picture transmission, carrier current, radio, television, and varied requirements of central office equipment. Six thousand or more conditions must be met as to values of capacitance, precision adjustment, dielectric strength, and other factors. By increasing attention to the design, this large variety of conditions is being met with a constantly reduced number of types of condensers.

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* *Development of the Impedance Bridge, S. J. Zammataro, pp.* 150-154.

* *The Electrolytic Condenser, by H. O. Siegmund,* Bell Laboratories Record, *Vol.* 4, *No.* 2. *pp.* 276-279, *April,* 1927.

NEWS

and Pictures of the Month

including

Activities of the Club



The Laboratories plane, with D. K. Martin, Thomas Durfee, and W. C. Tinus in the foreground. This picture was taken at Hadley Field, in connection with the first public demonstration of two-way radio telephone conversation between a plane and the lines of the Bell System

News Notes

H. P. CHARLESWORTH attended the Bell System Operating Conference held at White Sulphur Springs.

Mr. Charlesworth has been elected Chairman of the New York Section of the A. I. E. E., which has a membership of about four thousand in the metropolitan district. In this capacity he will also serve as a member of the New York Reception Committee of the American Committee of the World Engineering Congress. A number of European delegates will pass through the United States next fall on their way to the World Engineering Congress in Japan, and the New York Reception Committee will see that they are properly welcomed.

* * *

ON MAY 7 the Laboratories played host to the Society of Motion Picture Engineers, in four-day session at its New York City meeting. Papers were read in the Auditorium — among them *A Machine for Cutting Master Disc Records* by D. G. Blattner and L. A. Elmer, and *A Reproducing Machine for Picture and Sound,* by H. Pfannenstiehl — luncheon was served in the restaurant, and a demonstration of television was conducted by H. E. Ives.

* * *

AS A FEATURE of its annual meeting, fifty-seven members of the New York Section of the Student Branch of the American Institute of Electrical Engineers paid a visit to the Laboratories on April 26. Assembling in the Auditorium, they were welcomed by G. B. Thomas, then escorted through the Laboratories by A. F. Noe, H. C. Essig, E. T. Stammer, C. N. Stephan and P. M. Neave.

* * *

DURING the first week of May, our airplane radio equipment and personnel participated in two demonstrations of telephone transmission between the plane and distant points, employing wire and radio links. The first on May 1, was under the auspices of the Western Electric Company, for whom the equipment was developed. A group of newspaper men made flights from Hadley Field, during which they talked with their papers and dictated stories about what they saw and about the equipment used. These stories appeared prominently in the metropolitan dailies. The procedure was that after communication had been established between the plane and the ground station at Whippany, a connection was made with the Whippany central office of the New Jersey Bell Telephone Company and the telephone call was put through in the usual manner. In all cases the transmission and reception were reported as excellent.

On Saturday May 4, the plane was connected with Mr. Charlesworth, who was at White Sulphur Springs, at a conference of Bell System executives. While those present at the conference listened through loud speakers, Capt. A. R. Brooks, our chief air pilot, carried on a short two

way conversation with Mr. Charlesworth and gave a brief description of the radio equipment and the day's flying conditions.

In general charge of the demonstrations were E. L. Nelson and F. M. Ryan. At Whippany were D. K. Martin, L. G. Young, W. K. Caughey and E. S. Dobson; at Hadley Field and in the plane were F. S. Bernhard, W. C. Tinus, W. E. Reichle, A. R. Brooks, and Thomas Durfee.

* * *

THE MEETINGS of the Acoustical Society of America were held in the Auditorium on May 10 and 11. Of the twenty-five papers presented, seven were by members of the Laboratories: *Tube Method of Measuring Sound Absorption*, by E. C. Wente; *Description and Demonstration of Artificial Larynx*, by R. R. Riesz; *Articulation Testing Methods*, by H. Fletcher and J. S. Steinberg; *The Dynamics of Vibration of the Vocal Cords*, by R. L. Wegel; *Speech Power and Its Measurement*, by L. J. Sivian; *The Effect of Distortion on the Recognition of Speech Sounds*, by J. C. Steinberg, and *Methods and Apparatus for Measuring the Noise Audiogram*, by R. H. Galt. Members of the society were guests of the Laboratories at lunches during the convention.

* * *

AT A JOINT MEETING of the acoustical and motion picture societies in the Auditorium on May 9, H. D. Arnold delivered a demonstration lecture on *Acoustic Facsimile*.

SYSTEMS DEVELOPMENT

S. F. BUTLER, C. E. BOMAN and H. E. MARTING visited Atlantic City and Wilmington to view the installation of a new type of superstructure in step-by-step offices.

L. M. ALLEN and S. B. WILLIAMS visited Atlantic City and Somers Point in connection with step-by-step equipment.

W. J. LACERTE and J. R. KIDD visited Olean, where new equipment for eight-party rural line service is being installed for trial.

J. W. GOODERHAM was called to Philadelphia and Harrisburg in connection with interference studies.

F. S. ENTZ spent several days in Detroit where an installation of repeaters in straightforward trunks is under way.

J. B. SHIEL was in Denver last month in connection with the installation of a new No. 3 toll board.

H. M. PRUDEN and C. C. MUNRO visited the Transatlantic Radio Station at Lawrenceville.

W. A. PHELPS and R. B. STEELE spent some time in Key West and Havana in connection with the carrier telegraph circuits on the Key West-Havana cables.

A. D. DOWD and L. A. O'BRIEN were in Philadelphia to test the picture transmission equipment being prepared for Manchester, England.

J. R. STONE was in West Lynn, Massachusetts, attending a Survey Conference with the General Electric and Western Electric Companies.

J. C. GREENE went to Atlanta to discuss with representatives of the Telephone Company the new No. 3 toll board to be installed there.

A. E. PETRIE and V. T. CALLAHAN inspected an ATT-4 gasoline engine installation at Buffalo.

EUGENE L. RUYMEN died in Long Island College Hospital on April 16. From 1904 to 1907 Mr. Ruymen was

in the shops as an assembler. Returning after a year elsewhere, he was associated with the Laboratory for local central office development as a laboratory assistant until his retirement in 1927.

F. E. MASEK visited Harrisburg and Pittsburg, in connection with the trial of high insulation test equipment.

F. L. MORGAN and R. P. JUTSON visited Netcong, where power equipment for the short-wave receiver is being installed.

W. J. BOHRMAN visited Somers Point, to inspect the power equipment used with the unattended step-by-step central office there.

L. P. BARTHELD was in Chicago to discuss test splices with members of the staff at Hawthorne.

F. T. FORSTER was in Philadelphia in connection with the tests to reduce evaporation in batteries of the open tank type.

T. PAUL observed a trial of harmonic ringing on eight-party semi-selective lines in Albany.

RESEARCH

DURING the week of April 13, H. D. Arnold, R. M. Bozorth, O. E. Buckley, K. K. Darrow, C. J. Davisson, H. Fletcher, F. S. Goucher, H. E. Ives, W. A. Marrison and W. Wilson attended a conference on "Certain Aspects of Atomic Physics" at the Loomis Laboratory, Tuxedo, New York. Dr. Davisson presented a paper on *Electron Waves*.

IN ADDITION TO THOSE who delivered papers, listed in the May RECORD, there attended the meeting of the American Physical Society in Washington A. L. Johnsrud, G. R. Stilwell, C. J. Davisson, L. H. Germer, A. L. Samuel, H. E. Mendenhall, H. H. Lowry, S. O. Morgan, E. J. Murphy, G. T. Kohman, P. P. Cioffi, F. S. Goucher, J. B. Johnson, and C. A. Kotterman. While in Washington Mr. Kotterman made an inspection of the telephone exhibit maintained by the Laboratories in the museum of the National Academy of Sciences and the National Research Council Building.

AT VARIOUS TIMES during April W. C. Jones, N. Blount, H. A. Larlee, E. W. Conger, and J. T. L. Brown were in Hawthorne in connection with the development of transmitters and receivers.

C. H. G. GRAY was in Hawthorne during the week of April 14 to confer on the application of machine testing methods.

H. H. LOWRY and W. B. WARREN revisited the Jeddo-Highland Coal Co., and W. E. Orvis inspected properties of the Lehigh Valley Coal Co. at Hazelton and Drifton, Pennsylvania, in an investigation of new sources of coal for transmitter carbon.

AT THE MEETING of the Colloquium on April 22, W. P. Mason spoke on *Acoustic Lines, Filters and Networks*. At the May 6 meeting, W. A. Marrison spoke on *A High Precision Standard of Frequency*, and F. R. Lack on *Observations on the Vibration of Quartz Plates*.

J. M. FINCH visited the Central Office at Wilmington, Delaware, for a study of insulating materials.

A. R. KEMP was in Hawthorne in connection with the study of cable development.

E. O. SPERR visited Philadelphia April 1 to 5 observing the accuracy of tolerance tests on creosoting oils.

A. R. OLPIN spoke before the faculty and graduates of New York University on "The Most Recent Developments in Improving the Sensitivity of Photoelectric Cells."

HARVEY FLETCHER attended a luncheon and meeting at Yale University which was called to formulate a program of research on speech and hearing. In the evening he gave a demonstration-talk on the mechanism of hearing and the use of 4-A audiometer before the New Haven League for the Hard of Hearing.

H. A. LARLEE has been elected a member of the Edward J. Hall Chapter of the Telephone Pioneers of America.

INSPECTION ENGINEERING

G. D. EDWARDS and A. G. DALTON visited the New England Telephone and Telegraph Company in Boston early in May in connection with Inspection Engineering work.

A. F. GILSON and S. H. ANDERSON visited the General Electric Company at West Lynn during the latter part of April and the early part of May to conduct a study of inspection and quality control methods as applied to telephone power machines.

T. L. OLIVER, Atlanta Field Engineer, visited New Orleans and several Mississippi cities during the last week of April in connection with field inspections of telephone equipment.

R. C. KAMPHAUSEN, Detroit Field Engineer, was in New York during the first week of May to confer with members of the Inspection Engineering Department concerning Field Engineering work.

E. G. D. PATERSON and O. S. MARKUSON attended the New York Electrical Society inspection of the John A. Roebling's Sons Company wire and wire-rope factories at Trenton and Roebling on May 2.

O. S. MARKUSON and D. S. BENDER visited Springfield, Massachusetts during the first week of May to observe installation processes used in connection with the new 1800-pair lead-covered cable.

APPARATUS DEVELOPMENT

The Outside Plant Development Department moved from the second and third floors of sections J and K at West Street to the 10th floor of the Maltz Building at 480 Canal Street on April 27.

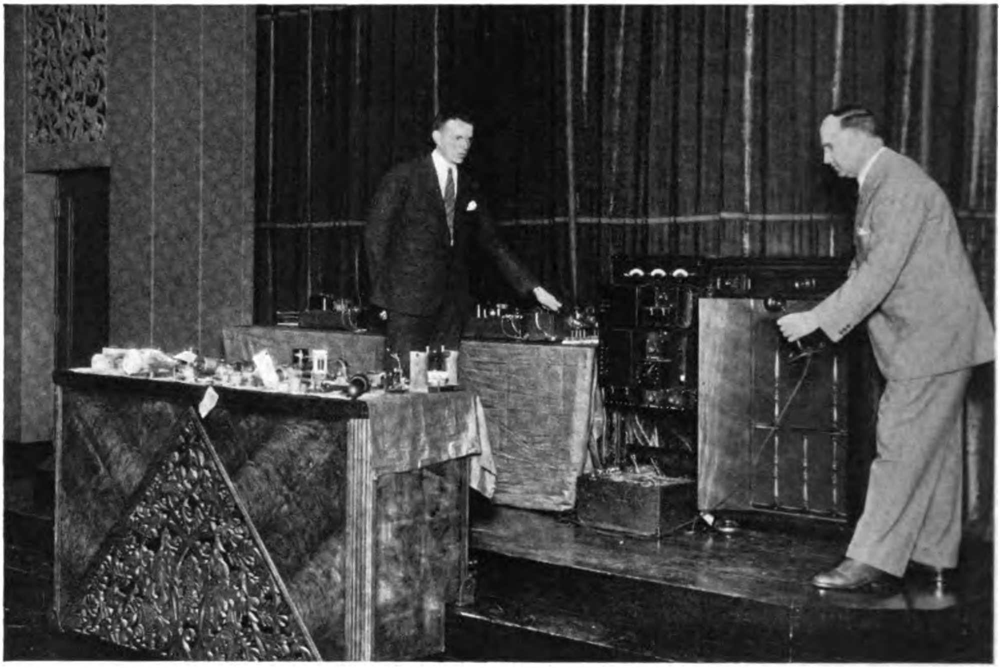
This space contains both offices and laboratories in about equal proportions. The work which is being done in the various laboratories can be briefly indicated by their names: Cable and Hardware, Wire Finishing and Tools, Timber Products, Concrete and Conduit, Electrical Measurements, Artificial Weathering and General. The General Laboratory contains such apparatus as a wire tensile machine, a rubber compression machine, and an Amsler machine for testing a variety of materials in tension, compression and transverse bending.

Members of the Department may be reached by telephone from West Street through tie lines to the Canal Street PBX by calling "Canal Street," or from outside by calling Walker 0380.

D. D. MILLER visited Hawthorne during the week of April 22 for conferences on new relay developments and work of the American Engineering Standards Committee on gauges for wire and sheet metal.

F. J. REDMOND was at Hawthorne recently in connection with new developments in dial number plates.

J. D. TEBO visited Hawthorne during the week of April 29 on an inspection trip arranged to familiarize members of the Laboratories with manufacturing conditions.



S. P. Grace, and R. M. Pease of the Apparatus Development Department, demonstrate some recent developments of the Laboratories

J. ABBOTT visited Hawthorne during the week of April 22 with J. M. Labaugh of A.T.&T. in connection with new equipment for adjusting and inspecting dials.

C. D. HOCKER made trips to Pittsburgh and Altoona during the latter part of April with members of the American Society for Testing Materials to inspect outdoor exposure tests on galvanized metal.

C. R. MOORE visited Kearny on April 27 to investigate methods of loading and blocking cable reels in railway cars.

G. Q. LUMSDEN, accompanied by Mr. Lindsay of the Mountain States Telephone and Telegraph Company, made an inspection of lodge-pole-pine and cedar poles in the Lordsburg-Duncan line of that Company in connection with timber preservation studies during the latter part of March and the first part of April.

R. P. ASHPAUGH, of the Outside Plant Development organization in Hawthorne, visited New York from April 15 to April 24 to witness experimental field tests on cables.

W. E. MOUGEY, of the Outside Plant Development organization in Kearny, made a trip to Fort Worth, Texas, during the latter part of April to observe the handling of the new tape-armored toll cable which is being installed there.

A. B. BAILEY directed the installation of the new speech-input equipment at Station WABC of the Columbia Broadcasting System.

N. BISHOP inspected the one-kilowatt broadcasting equipment of the Oregon State Agricultural College, and the five-kilowatt broadcasting equipment of the Western Broadcasting Company at Hollywood.

B. R. Cole supervised the installation of the one-kilowatt broadcasting equipment for the Outlet Company at Providence.

J. C. Herber made a survey for one-kilowatt broadcasting equipment for the Toledo Broadcasting Company. He also inspected the five hunded watt broadcasting equipment of Strawbridge and Clothier, Inc., of Philadelphia.

O. W. Towner made a survey for one-kilowatt broadcasting equipment for the Reynolds Radio Company at Denver. He inspected the one-kilowatt broadcasting equipment for the Gurney Seed and Nursery Company, Yankton, South Dakota, and the Kansas City Star.

C. E. Lane attended the Dallas regional meeting of the A. I. E. E. and presented a paper prepared jointly with T. E. Shea on *Transmission Networks—Types and Problems of Design*. He also assisted in Mr. Grace's lecture there by demonstrating the operation of the artificial larynx.

Several members of the General Apparatus Development Department, including W. Fondiller, W. J. Shackelton, H. N. Van Deusen and F. F. Lucas, took a trip arranged by the New York Electrical Society to the John A. Roebling Sons Company plant at Trenton on May 3. The visitors saw the manufacture of telephone cable and various wire products, including the suspension wire for the new Hudson River Bridge.

C. R. Young and H. A. Anderson, with C. B. Evans of Hawthorne, visited the General Electric Company at Schenectady on May 6 to discuss improvements in methods of welding loading coil cases.

J. R. Townsend delivered a talk on non-ferrous alloys at one of the technical sessions of the Chemical Exposition at Grand Central Palace.

On May 10 F. F. Lucas, H. A. Anderson, R. M. Sample, C. H. Greenall and I. V. Williams attended the sectional meeting and inspection trip of the American Society for Steel Treating at the Bethlehem Steel Company.

General Staff

Edward Buttner, a shop mechanic with forty-three years of Bell System service, died at his home on May 2. His was an unusual record—of thirty-nine years of shop service without accident, injury or sickness. Coming to West Street in 1886, he operated a milling machine in the Engineering Shop until 1925, save during two years spent at Hawthorne and a short time in the Tool Room. The Laboratories regrets the termi-



Edward Buttner

nation of nearly a half-century of devoted and valued assistance.

Augustine W. Caras died at the Methodist Episcopal Hospital in Brooklyn on April 22. From 1922 to 1925 Mr. Caras was a member of the Payroll Department of the Western Electric Installation Department. On June 14, 1925, he joined the Expense Accounting Department of the Laboratories.

G. F. Fowler addressed the annual convention of the Boston Alumni of Worcester Polytechnic Institute at the City Club of Boston on "Side Lights on Communication."

L. S. O'Roark talked on April 25 before 200 members of the Mountain Lakes Men's Club on "Why Men Cannot Understand Women." During May he spoke on "The Photoelectric Cell and Its Application to Communication" to two hundred electrical and mechanical engineering students of the senior class of Cornell University, and to the Engineers' Club of Dayton, Ohio. Mr. Fowler accompanied him to Cornell and demonstrated sound pictures.

Demonstration lectures on sound pictures were given by W. C. F. Farnell before 150 telephone employees at the conference of the General Board of the Southern New England Company's Employees' Association at Norfolk, Connecticut, and by P. B. Findley, assisted by Mr. Fowler, before the Boston Post, American Signal Corps Association, on May 22.

S. P. Grace gave a talk to the department heads of the Southern Bell Telephone and Telegraph Company in New Orleans on May 4. On May 7 Mr. Grace addressed the Regional Convention of the Seventh District of the A. I. E. E. in the ballroom of the Adolphus Hotel, Dallas, Texas. About six hundred Dallas people and four hundred engineers and students from all parts of the Southwest were present.

John Mills addressed the Western Universities Club of New York City on April 23. At the Washington Convention of the Institute of Radio Engineers he gave a description of sound pictures, accompanied by a demonstration by Mr. Farnell.

During April M. B. Long visited the University of Pennsylvania to interview 1929 engineering graduates interested in Bell System employment, and R. A. Deller visited the University of Michigan, Case School of Applied Science, Ohio State, and Penn State to follow up employment offers previously made.

G. B. Thomas was in Boston in connection with the cooperative plan for students carried forward by the Laboratories and Massachusetts Institute of Technology.

Helen M. Craig attended the annual conference of the Special Libraries Association in Washington during the week of May 13.

Patent

Between April 10 and May 7 G. C. Lord, J. F. McEneany, M. R. McKenney, T. P. Neville, C. A. Sprague, and W. B. Wells visited Washington for the prosecution of patents.





Vail Medal Awards for 1929

FOUR silver medals have been awarded by the National Vail Medal Committee to men and women selected from the fifty-two to whom bronze medals were awarded during 1928 by Associated Companies of the Bell System. ¶ To be selected for National Vail Medal recognition an act must have for its objective the accomplishment of something of real value in the public interest through the medium of Bell System facilities, organization, training or experience, and must reveal to a high degree many, if not all, of the positive qualities of intelligence, initiative and resourcefulness, and usually courage, endurance and fortitude.

Awards and Citations

Mrs. Mabel Hite, *Agent, Northwestern Bell Telephone Company, Potter, Nebraska.*

For alertness and responsiveness in sensing an emergency under unusual circumstances and for initiative and resourcefulness resulting in the saving of life and the accomplishment of an important communication service.

On the evening of February 17, 1928, while on duty alone at the telephone central office, Potter, Nebraska, she heard overhead the sound of an airplane and noted that it continued for some time as though the plane were circling over the town. A blizzard was raging at the time, and she deduced from the unusual behavior of the plane that the pilot must be lost or in other difficulty. She therefore immediately called the Air Mail field about twenty miles east of Potter and received advice that the most helpful action under the circumstances would be to mark out the boundaries of a possible landing field with red flares which might be obtained from the railroad company. She called a local garage and explained the emergency and the action which

should be taken. The garage man secured help and marked out a landing place, thus enabling the pilot, who was carrying United States mail, to land safely, refuel the plane and continue on his way.

* * *

OLIN ETHERIDGE PERDUE, *Line Measurer, Long Lines Department, American Telephone & Telegraph Company, Atlanta, Georgia.*

For courage, resourcefulness and persistence in the rescue and resuscitation of a fellow employee.

On September 14, 1928, when a fellow employee, encumbered with a heavy tool box and climbers, had fallen into the flood swollen Altamaha River, near Jesup, Georgia, he dived from a twenty foot trestle, risking his life to save his comrade. He reached the man, brought him to the surface and fought his way fifty yards through floating debris to the river bank but, with his helpless burden, he was unable to reach firm ground at this point. Standing on the submerged branch of a tree, he hauled the now unconscious man up into the branches and unstrapped and cast off the heavy tool box and climbers, after which he again fought his way twenty-five yards further through the flood to some logs that had lodged against a tree. Here he pulled his comrade out of the water onto the logs and applied artificial respiration, restoring him to breathing and consciousness.

* * *

MRS. ALTHEA P. MARKS, *Agent, The Pacific Telephone and Telegraph Company, Saticoy, California.*

For courage and devotion to the public service during an emergency.

On March 13, 1928, at about 12:40 A.M., on answering a call at the central office switchboard in her home in Saticoy, she learned that the St. Francis dam had broken and that the entire Santa Clara River Valley was in danger of being flooded. Although aware that the enormous amount of water impounded by the dam might inundate the town, she remained at the switchboard, warned the residents of the community of the impending danger, calling those she could by telephone, and directing messengers to others. She kept everyone informed as to the progress of the flood and after it subsided she continued without respite for three nights and two days to render essential public service in connection with relief work.

* * *

ANNA C. YURECSKO, *Night Operator, New Jersey Bell Telephone Company, Rockaway, N. J.*

For resourcefulness and intelligent action in an emergency.

Late in the night of June 24, 1928, while on duty alone in the telephone central office, Rockaway, New Jersey, she learned from a subscriber of an automobile accident in which the car had crashed over a railroad bridge and fallen onto the tracks, blocking the passage of oncoming trains.

Realizing the seriousness of the hazard that the wrecked car created on the railroad tracks and that a train was soon due to reach that point, she undertook to stop this train in time to prevent a second accident. She was unable to communicate directly with the only signal tower from which the train could be stopped, but telephoned the warning to the train dispatcher's office some fifteen miles away, and through that office got word to the signal tower over the railroad's private telephone line. After being assured of the safety of the train, she summoned police aid for the injured who had been rescued from the wrecked automobile.

Contributors to this Issue

L. A. O'BRIEN received the B.S. degree in electrical engineering from Kansas State Agricultural College in 1914, and returned there to receive the E.E. degree in 1919, after four years with the Equipment Engineering Department of the Western Electric Company. After two years as Employment Manager for the Dain Manufacturing Company, and two years as Production Engineer of the National Carbon Company's Jersey City works, he came to the Systems Development Department of these Laboratories. During his first three years here Mr. O'Brien was concerned with toll equipment development, including that of picture transmission. He has since been working with the development of local systems.

* * *

R. E. COLLIS received the M.S. degree from Iowa State College in 1917 and came to the Laboratories the same year. From 1917 to 1922 he was engaged with the development of the printing telegraph. In 1922 he was transferred to the Systems Development Department, where he is now concerned with special problems relating to the panel type of dial telephone system.

* * *

M. K. KRUGER graduated from St. Lawrence University in 1920, and entered these Laboratories that fall. After a brief period in the Transmission Department and about a year and a half in the Physical Laboratory, he was transferred to the Educational Department, and in 1926 to the group in the Apparatus Development Department engaged in the design of filter networks.

* * *

C. R. YOUNG received the B.S. degree in electrical engineering from the University of Vermont in 1900, and came in that year to West Street to join the Western Electric Company's Inspection Department. He was later transferred to the design



R. E. Collis



L. A. O'Brien



M. K. Kruger



C. R. Young



R. S. Wilbur



R. Raymond

section of the Engineering Department, and is now concerned with the design of loading coil assemblies and cases.

* * *

ON GRADUATION by Cornell University in 1900, R. Raymond entered the engineering department of the Western Electric Company where he had an important part in development of early common-battery circuits. He was identified with panel switching developments from the outset. One of his major contributions during the early panel stages was the preparation of a key sheet for each job to specify the circuits necessary to meet individual traffic requirements. In the laboratory study of the coordinate system, Mr. Raymond was responsible for development of operative circuits. His most recent activity has been the development of the decoder, which he described in the RECORD for May, 1928.

* * *

R. S. WILBUR began his telephone experience in the independent field in 1899. After eleven years in telephone operating and manufacturing companies, he joined the Circuit Laboratory at West Street. In the Systems Development organization he has participated in manual and toll development and is now Toll Circuit Engineer.



Bell Laboratories Club

It had been rumored that there were Talleys and Tibbetts in our Glee Club, and it was not without a certain conviction to that effect that an audience of seven hundred heard and applauded an excellent program given at the Hotel Pennsylvania, April 26. The singers gave pleasing evidence of the time and diligence which had gone into preparation for the evening's entertainment. The large ballroom was well filled and most of the boxes occupied when Mr. Richards mounted the rostrum to direct the first number, "Allah's Holiday." Other numbers by the Glee Club which were well received were "Dreaming" and "Swing Along." Solos by Russell P. Yeaton, tenor, and Francis M. Costello's baritone rendition of "Captain Mac," were especially liked. Dorothy M. Allyn, soprano, sang "Dawn" with Friml's "L'Amour, Toujours l'Amour" for encore and was presented with a bouquet of American Beauty roses which genuinely expressed the appreciation of the audience. Other numbers by the Women's Chorus and the Men's Chorus evinced Mr. Vere S. Richards' very capable direction of the Glee Club. Ada I. Van Riper and P. H. Betts were the managing committee for the Club.

After the concert, Hood's Orchestra, augmented to fourteen pieces, provided music for dancing and by smart playing of popular numbers found little competition with the punch bowl and lounging foyer in attracting the dancers for the remainder of the evening.

The Glee Club Celebrates

The Glee Club sang its finale at a party at Keen's Chop House Wednesday evening, May 1. Forty-four of our amateur songsters exhibited a familiarity with the dining fork equal to that with the tuning variety. At the dinner, appreciation was expressed to Ada Van Riper and P. H. Betts of their enthusiastic efforts in helping to make the Glee Club season a success. By dint of an excellent dinner, the party grew expansive and adjourned to a private hall, there better to celebrate the festival to Orpheus.

Vere S. and Mrs. Richards again contributed some of their cleverly executed games which were thoroughly enjoyed. The games were interspersed with songs, a harmonious duet and an amusing ad lib of the Miserere Chorus.

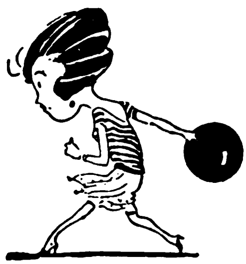
Finally the evening ended with hearty cheers for Director and Mrs. Richards as an expression of thanks for their part in the season's success and au revoirs were said until next fall.

Women's Bowling

"Bowling Them Over," the play presented by the Women Bowlers of the Bell Laboratories Bowling

League on Monday, May 6th, was an eminent success.

The prologue opened at the County Fair restaurant, where the play was given, to a scene of unusual gaiety. Besides the bowlerettes who had gathered for this final reunion, there were present as guests sev-



eral members of the Men's Bowling League, whose valuable assistance had contributed toward the success of the women's bowling season. Prominent among them were O. M. Glunt and H. F. Dodge, President and Vice-President, respectively, of the Bell Laboratories Club.

As an aid to appetites H. F. Dodge and Miss Melita staged an impromptu derby just before dinner on the outer "racetrack" of the dance floor with two grotesque wooden steeds provided by the management of the County Fair. Bulletin: weather fair, track slippery. Contrary to ground rules, the fair jockey did *not* win the race.

At the close of a speech, replete with stories for which he is famous, Mr. Gilson as Chairman of the Bowling League awarded prizes.

A pocketbook was awarded to each of the following members of the winning team (Rulers):

Antoinette Kelly
Leona Feil
Lee Melita
Dorothea Jacobs
Lillian Cunningham

Each of these members of the second highest team (Erasers) received a string of crystal beads:

Elsie Baran
Martha Kapusinsky
Martha Niebob
Margaret Tully
Helen Bortfeldt

The prizes for the season's high averages were as follows:

Antoinette Kelly—Silk umbrella
Natalie Skinner—Crystal beads
Leona Feil—Compact

The prizes for the season's high scores were awarded to the following:

Lee Melita—Parker fountain pen
Dorothea Jacobs—Parker pencil
Natalie Skinner—Bridge set

The grand surprise of the evening was a special prize donated by D. D. Haggerty for the greatest improvement in average for the entire season. In awarding this prize, a fine aquamarine brooch, Mr. Haggerty commended the winner, Dorothea Jacobs, on the remarkable improvement she had made.

Speeches were also made by H. F. Dodge, O. M. Glunt and D. R. McCormack.

After the dinner the girls attended the performance of "Lady Fingers" and the men dejectedly went home.

The Male Bowlers Dine

The pilgrimage from West Street to Two Park Ave.... The smoke-filled billiard room where losers at bowls triumphed at Kelly pool... The statue of Nathan Hale which Bob Nossaman mistook for a guest ...The wild search for the place-card...The well-aimed grapefruit-juice...The hardworking "black-in-the-face" orchestra...The rainbow 'round the shoulder . . . The chairman—Al Gilson—who swung a wicked gavel as toastmaster...The

Prize Winners of the Bowling Season

LEADING TEAMS

A	B	C	D
***Buzzers**	*Signals*	*Coils*	*Plugs*
Won 49, *Lost* 35	*Won* 50, *Lost* 34	*Won* 52, *Lost* 32	*Won* 52, *Lost* 32
R. J. Miller	C. White	F. G. Buhrendorf	W. R. Steeneck
J. R. Kidd	R. S. Wilbur	H. A. Lewis	H. O. Wood
C. L. Deelwater	J. Babcock	E. A. Wieland	E. F. Ketcham
E. J. Johnson	A. G. Jeffery	H. W. Schaeffer	L. C. Dikeman
W. P. Trottere	T. V. Curley	A. G. Eckerson	L. H. Bachmann

SECOND TEAMS

**Plugs*	*Buzzers*	*Lamps*	*Relays*
Won 49, *Lost* 35	*Won* 49, *Lost* 35	*Won* 51, *Lost* 33	*Won* 47, *Lost* 37
C. E. Flaig	F. S. Entz	A. G. Lang	J. Meszar
J. Umschied	A. W. Hawley	F. W. Treptow	C. G. Gerth
F. A. Korn	C. W. Green	H. W. Hodgkins	F. F. Stoner
H. Rosenbohm	V. J. Hawks	E. K. Eberhart	O. H. Danielson
A. W. Dring	H. W. MacDougall	C. G. VonZastrow	H. LaFrenz

* Tied.

HIGH TEAM SCORES

Ringers	*Signals*	*Coils*	*Lamps*
Score 1005	*Score* 931	*Score* 909	*Score* 905
J. Dusheck	C. White	F. G. Buhrendorf	C. C. Kingsley
A. M. Elliott	R. S. Wilbur	H. W. Schaeffer	T. V. Borlund
R. J. Nossaman	J. Babcock	H. A. Lewis	J. M. Peabody
C. J. Hay	A. G. Jeffery	E. A. Wieland	C. R. Taft
T. C. Rice	T. V. Curley	A. G. Eckerson	A. D. Ligouri

HIGH INDIVIDUAL AVERAGES

Dieffenbach ...183.27	Lohmeyer 168.75	Kobylarz 160.33	Steeneck 149.96
Rice 181.10	Boyles 166.93	Lewis 155.26	Taft 148.28
Muller 179.64	Entz 166.92	Pullis 154.44	Bendernagel ..146.59
Flaig 176.99	Held 165.81	Bollinger 153.88	Paulssen 146.19
Miller 176.73	Wilbur 164.97	Buhrendorf ...151.81	Meszar 145.98

HIGH INDIVIDUAL SCORES

Fairlamb 256	Greene 249	Scribner 238	Ligouri 223
Bodenstedt 254	Wilbur 247	Reybert 236	Paulssen 221
Rice 251	Boyles 235	Lewis 230	Parker 221

results of the season's rolling, as told by L. E. Parsons...The presidential remarks by O. M. Glunt...The doubling of Mr. Dixon for Mr. Charlesworth...The ditto by Phil Norton for Dr. Jewett...The little



group of serious bowlers selected by James A. Wilson for individual honors...The disintegration...The long wait for overcoats...The choice of subway or taxi...The search for the theatre-ticket...The show-girls and comedians who made pleasure abound ...The commuters in inside seats who must catch the 11:15 to Mud Lake... The grand exit....

Splits and Slices

As between after-dinner speeches, profound or humorous, the stags at the bowling dinner showed a distinct preference for a song which purported that the scarcity of women was ruinous to the party.

After which many were seen to leave the table ostensibly to make phone calls, never to return — in spite of A. F. Gilson's magnetism as a story teller.

The mezzanine at the Majestic Theatre acquired a telephone complex when 225 satisfied banquet bowlers perched there like sparrows on a bank of phone wires, the actors catching the mood and wise-cracking for the betterment of telephone service.

In the midst of victory comes defeat. Equal in dramatic effect to the football player who ran 60 yards to the wrong goal, Tom Rice carefully split his last bowl in the Bell System League play-off and went down to a glorious defeat.

BATTER UP

With the cry of "play ball" heard in opposite ends of Brooklyn on Saturday, May 4, the Club Departmental Baseball League opened the



1929 season. At Farmers Oval an exciting and close game was played by the Systems Development Department and the Ringers, a team composed of ball players from the Apparatus Development, Research, and Commercial Departments. The Systems team won the game. At Erasmus Field on the same day the Tube Shop team defeated the team representing the Plant and Shop Department of West Street. Games are scheduled at both ball parks on the Saturdays in May, after which all games will be played at Erasmus Field.

On Wednesday evening, May 8, the Laboratories' team in the Bell System League played its first game and was defeated, 4 to 2. Its op-

ponent for the evening was the Western Electric Company, Brooklyn team. The Laboratories' team in the Bell System League will play games on June 11, June 19 and June 25.

Swim and Save

The swimming season is here with its bright panoply of blue skies, white sands, brilliant-hued beach wear and —unguentine. The wise ones are running down to Brighton Beach evenings, Saturdays and Sundays, taking advantage of the conveniences offered by our arrangement with the Beach management and avoiding crowds, long queues and extra expense.

Tickets may be purchased from the Club Secretary at one-half the regular price, entitling the holder to full privileges. Tickets for Sundays and holidays are one dollar each. Club membership cards are necessary with the admission tickets.

For those who would avoid the devastating effects of the sun there is the Shelton Hotel pool available to our members for the summer season. This arrangement offers a reduction in regular price, the seventy-five cents charged being one-half the regular rate. The Shelton is convenient, is open to both men and women, has splendid facilities, including restaurant, lounge and library, in addition to the excellent pool.

The Class in Rhythm Graduates

The Rhythm classes at the Noyes School of Rhythm were concluded on May 14 with a short program of Lyric-Drama Dances by Miss Catherine Rapp of the school.

The exhibition illustrating rhythm, as formed in the dance, was highly interesting to the class. The classes in rhythm undertaken somewhat as an experiment have definitely proved to be beneficial and instructive. It is expected to resume the classes in the fall when more who are interested will have an opportunity to take part.

New Course for Women Golfers

Golf promises to be one of the most popular outdoor sports for women if we are to judge by the excellent course which has been tentatively selected as the locale for this sport. The Tyson Manor Golf Club course on Staten Island is particularly suitable and offers many advantages.

Interested golfers should learn more about it from Marion Kane.

Bridge Season Ends

May Lynch and G. T. Lewis arranged an enjoyable bridge party on April 22 to close the men's and women's bridge season. The winners were:

First Men's Prize

E. H. Leonard — 1584
O. L. Michal

First Women's Prize

Misses Lynch — 1457
and Munn

Second Men's Prize

J. C. Field — 1141
J. E. Clark

Second Women's Prize

Misses Haunfelder — 795
and Wilson

It is planned in the Fall to have a bridge for the girls at the Happiness Restaurant, Fifth Avenue and 44th Street. This party is being arranged to stimulate interest in the weekly bridge games during the winter.

Telephoning to Trains

On May 6, *the newspapers carried an account of successful experiments in telephoning from a moving train of the Canadian National Railways. Duplex transmission was employed, using separate frequencies for sending and receiving. Separate antennas were on the roof of one car, and the ground station was connected to the open-wire line along the route, half the wires being grouped for the receiving channel and the other half for the transmitting channel. Technical phases of the tests were directed by J. C. Burkholder, formerly of these Laboratories, who went to the Canadian National Telegraphs early in* 1928 *in connection with its purchase of carrier telegraph systems from Northern Electric.*

On account of the Bell System's prominence in the communications field, some of the newspapers enquired of the American Telephone and Telegraph Company as to similar facilities in this country. President Gifford made the following statement:

"For some years the American Telephone and Telegraph Company has been ready to install telephone service on moving trains, and about two years ago had the matter up actively with two of the leading railroad systems in the country. Both railroads decided against it as it was not considered commercially practical. If any railroad wishes to give such service on its trains and bear the necessary cost of it we shall be very happy to install it and connect it with the lines of the Bell System."

BELL LABORATORIES RECORD

A WELCOME TO NEW MEMBERS
By H. P. Charlesworth

TRANSATLANTIC SHORT-WAVE RADIO
By W. Wilson

TELEVISION IN COLOR
By H. E. Ives

JULY 1929 VOL. 7 NO. 11

Bell Laboratories Record

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Bell Laboratories Record

Volume Seven JULY, 1929 *Number Eleven*

A Welcome to New Members of the Laboratories

By H. P. CHARLESWORTH
Vice-President

TO meet the steadily increasing demands of its technical problems and its enlarging responsibilities Bell Telephone Laboratories must add correspondingly to its personnel, as well as expand its buildings and equipment. Losses by transfer to other companies of the Bell System, by death, and by severence of employment must also be offset by adding new employees. Such additions, although made continuously throughout each year, are most frequent during the early summer at the conclusion of the school year. This present summer about 500 young men and women will join our Laboratory forces.

It is my privilege, on behalf of the Laboratories, to address a word of welcome to those of you who are now joining your efforts to ours, and will contribute your energies and zeal to our common cause, Bell System service. It is indeed a pleasure to welcome you to this organization, knowing the far-reaching importance of the work which the Laboratories is carrying on in the field of communication, and the excellent opportunities which it offers to each individual for progress and satisfaction. That these opportunities shall continue and that your work shall be efficiently coordinated in our group efforts, is our responsibility, but what you make of these opportunities will depend largely, of course, on your own abilities and your effective team work with those about you.

Our work is indicated by our name, Bell Telephone Laboratories. We are a unit in the system of Bell companies, headed by the American Telephone and Telegraph Company. As Walter S. Gifford, President of that Company, has said, the prime incentive in the work of the Bell System is furnishing ever better and more comprehensive telephone service, at the least possible cost to the public. We are the Laboratory unit of that system, concerned with all the development, designing, engineering and research

work which can best be carried out in a laboratory.

In accordance with the general program of research initiated by the American Telephone and Telegraph Company we carry on basic laboratory investigations in the electrical arts of communication and in the phases of science fundamental to these arts. From these investigations arise new methods of communication, new materials and new principles. These take form in apparatus and equipment which are designed in our Laboratories. As such new equipment or systems are adopted for Bell System use they are specified to the Western Electric Company for manufacture. That company, the manufacturing unit of the System, also looks to the Laboratories for certain engineering services in connection with the equipment which it manufactures or supplies to the operating companies of the System.

These two companies furnish funds for our Laboratory operations, each paying the cost of the services rendered to it. In addition a portion of the development work in the Laboratories, and a corresponding part of the funds which it receives, is undertaken for a subsidiary of the Western Electric Company, Electrical Research Products, Incorporated. This company handles certain by-products of our work, outgrowths of our telephonic researches, such as the systems for sound pictures, which have application beyond the field of the Bell System's broad objective of communication service. A certain amount of manufacturing, large of itself, but small as compared to the enormous volume of the Western Electric Company, is also carried on by the Laboratories in its Tube Shop. Here are made, under the direction of the Laboratories Research Department, all the vacuum tubes and photoelectric cells for the Bell System and for other Western Electric equipment. Taking the total of all its activities the Laboratories at present has a force of about 5,200 and its present expenditure is at the rate of nineteen million dollars a year.

In some part of this large organization, and concerned with one of its many responsibilities, each of you who join with us, will find work which has an important bearing in our program of ever keeping the Bell System in the forefront of the communication art; a task in which you will find great satisfaction and pride of accomplishment. We who have preceded you, in entering upon this interesting work, take great pleasure in welcoming you to this important branch of the Bell System activities.

New Short-Wave Radio Stations

By W. WILSON

Assistant Director of Research

NEW short-wave stations for transoceanic communication have been opened at Lawrenceville, New Jersey, for transmitting and at Netcong, New Jersey, for receiving.

Four channels will be put into operation. One of these will replace the present experimental channel, through which messages have been transmitted from our Deal Beach station and received at Netcong for the last two years.

Two of the others will be added to the European service during the coming months, and the fourth will establish telephone communication with South America.

The Lawrenceville property is approximately 800 acres in extent and has two buildings. The main building houses the general offices and line terminal equipment in addition to two of the radio transmitters. The second building is similar to the first except that provision is merely made for the radio equipment.

Each transmitter is designed for operation on those frequencies in the short-wave range which are found to be necessary for communication during the hours of operation. These frequencies are approximately 19,000, 14,000, and 9,000 kilocycles, corresponding to 16, 22, and 33 meters wavelength.



Antenna towers and main building at Lawrenceville



Buildings at Netcong

Carrier power at these frequencies is obtained by amplification of the suitable harmonics from crystal oscillators with fundamental frequencies in the neighborhood of 3,000 kilocycles. Considerable care is taken with regard to constancy of temperature and other operating conditions to ensure the stability of these oscillators.

By the usual method of plate modulation, the voice signals are applied to the carrier, and the modulated power is in turn amplified by two stages employing water-cooled tubes. The output from the sets is fed by transmission lines to appropriate antennas, located in some cases several hundred feet away.

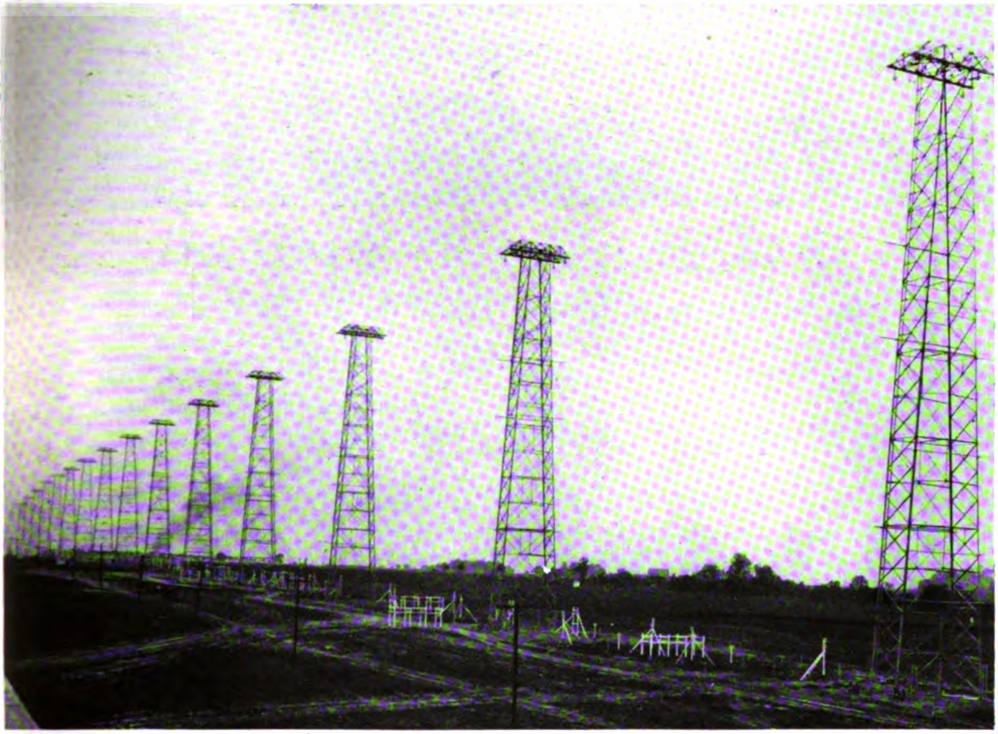
Power for the transmitter is purchased from central-station lines. After transformation to appropriate voltages, that required for plate circuits is rectified and filtered. For the two final stages power is delivered at 10,000 volts from a rectifier employing six water-cooled tubes. Elaborate precautions are taken to insure safety in operation by an interlocking system which prevents the opening of any enclosure before the power has been shut off. In addition the doors of the apparatus are equipped with



One of the short-wave receivers at Netcong. The monitoring operator's position is at the right-hand panel

safety switches which throw the main circuit breaker when the doors are opened if there should be any failure of the interlocking system.

One of the advantages of a short-wave system is its adaptability to the use of antennas which concentrate the transmitted energy into a beam in the direction required. This greatly enhances the signal at the receiver.

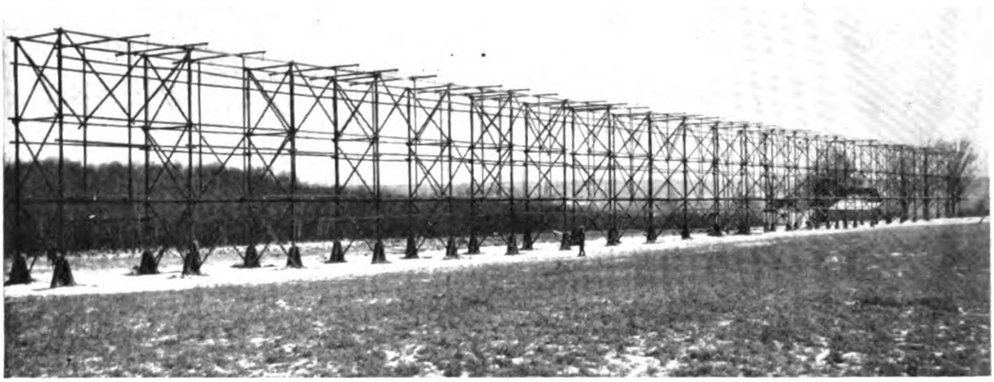


A general view of the antenna system at Lawrenceville

In general, directive antennas are suitable for only one wavelength. Since each transmitter must be able to work on any of three wavelengths, nine antennas are required. These consist of curtains of vertical and horizontal wires strung between towers 180 feet high and 250 feet apart. Each antenna is 500 feet wide and the nine antennas are lined up end to end giving a total length of 4500 feet. The gain to be expected from the use of these antennas over a single vertical wire is from fifteen to twenty decibels.

The Netcong receiving station comprises about 400 acres. As in the case of the transmitting station three wavelengths are needed for each of four receiving sets, necessitating the use of 12 antennas. Each receiving set is housed in a separate building and the general offices and power plant are in still another building.

The receiving sets have two stages of radio-frequency amplification, six stages of intermediate amplification and one stage of audio amplification. An automatic volume control minimizes fading effects. Actual volume at which the energy is put on the telephone line is adjusted by means of re-

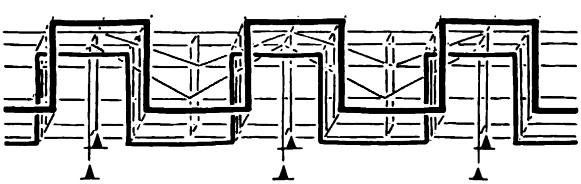


Receiving antenna at Netcong and its supporting structure

peaters in the line terminal equipment.

The antennas used at the receiving end are also directive. Their directivity not only makes them more efficient from the standpoint of picking up signals from a preferred direction but it also by its discrimination against signals coming from other directions materially reduces interference both from static and from other stations. The antennas are six wavelengths long and are connected to their respective sets by transmission lines.

In selecting a site for the receiving station great care was taken to avoid the proximity of well-travelled automobile and airplane routes, because of the interference with signals created by unshielded ignition systems. With the adoption of radio communication for airplanes their ignition systems must perforce be shielded but no relief can be expected from interference from the present type of automobile engine. Limits have been prescribed beyond which automobiles are not permitted unless their ignition systems are adequately shielded. Horses are used for much of the transportation immediately around the station.

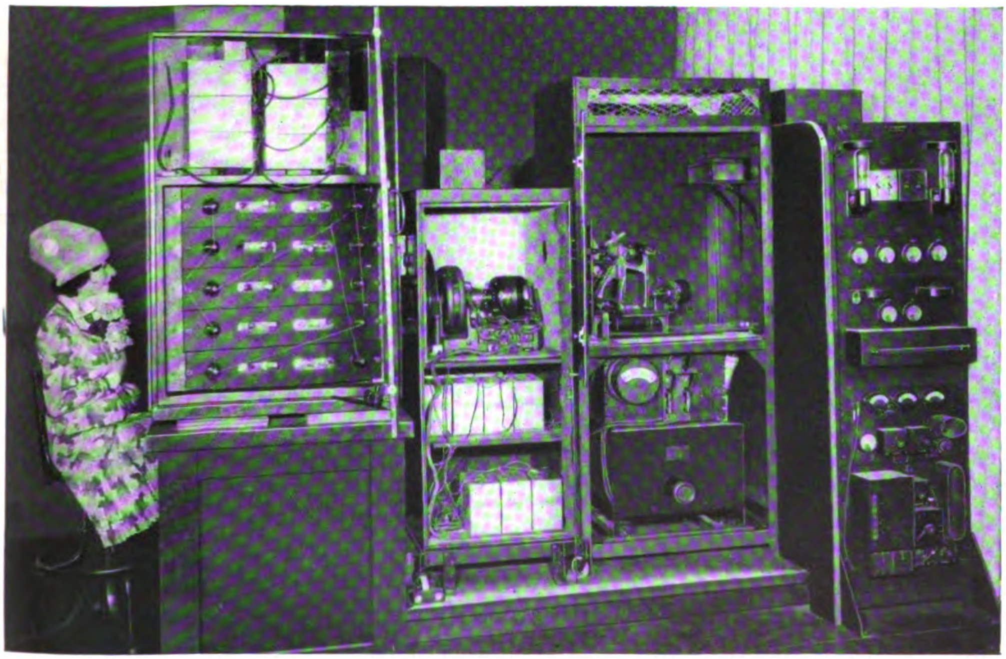


Television in Colors

By HERBERT E. IVES
Research Department

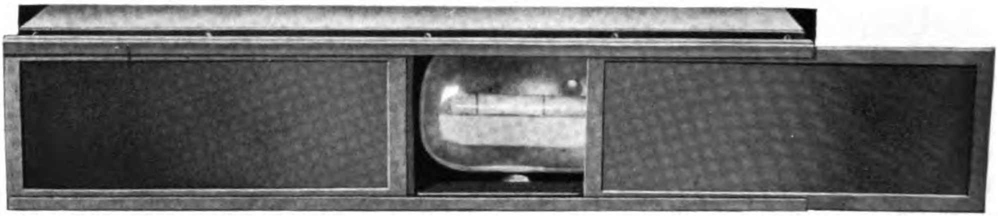
OVER two years ago Bell Telephone Laboratories demonstrated a practical system of television. For the first time successful representations of objects at rest or in motion were transmitted electrically — over wires or through the ether — for considerable distances. The reproduction of the scene then transmitted was in monochrome — the orange-red color of the neon lamp. Recent developments of the Laboratories, however, have made it possible to reproduce scenes with their true color values. The appearance of reality in the reproduced scene is thus greatly enhanced.

One of the most significant features of this new achievement is that it does not require completely new apparatus. The same light sources, driving motors, scanning discs, synchronizing systems, and the same type of circuit and method of amplification are used as in the monochromatic system. The only new features are the type and arrangements of the photo-electric cells at the sending end, and the type and arrangements of the neon and argon lamps at the receiving end. The out-



Side view of sending apparatus with doors of cabinets opened. With the exception of the photoelectric cabinet at the left, the apparatus is identical with that used for the original demonstration of monochromatic television

standing contributions that have made the present achievement possible are a new photo-electric cell, new gas cells for reproducing the image, and the ing landscapes in order to make the blue sky appear properly dark — this defect is corrected and the images assume their correct values of light and



One of the colored gelatin filters partly pulled back to reveal the color-sensitive photoelectric cell in the double container

equipment which is associated directly with them.

To render the correct tone of colored objects, it was necessary to obtain photo-electric cells which — like the modern orthochromatic or panchromatic plate — would be sensitive throughout the visible spectrum. This requirement has been satisfactorily met. Through the work of A. R. Olpin and G. R. Stilwell a new kind of photoelectric cell has been developed, which uses sodium in place of potassium. Its active surface is sensitized by a complicated process using sulphur vapor and oxygen instead of by a glow discharge of hydrogen as with the former type of cell.

The response of the new cell to color, instead of stopping in the blue-green region, continues all the way to the deep red. Because the former potassium cells were responsive only to the blue end of the spectrum, objects of a yellowish color appeared darker than they should have and the tone of the reproduced scene was not quite correct. This disadvantage applied particularly to persons of dark or tanned complexion. When the new cells are used in the original television apparatus and with yellow filters — similar to those used in photograph-

shade no matter what the color of the object or the complexion of the sitter. It is the availability of the new photo-electric cells which makes color television possible by their use.

The development of color television has been greatly simplified by the fact that as far as the eye is concerned any color may be represented by the proper mixture of just three fundamental colors — red, green, and blue. This fact was utilized in the development of color photography, and all the research that had been done in that field was available as background for color television. A host of methods of combining the three basic colors to form the reproduced image was available but, insofar as the sending or scanning end is concerned, a method was developed which has no counterpart in color photography. The method of "beam scanning" — used in the first television demonstration* — has been employed.

To apply this method to color television, three sets of photo-electric cells are employed in place of the one set used before. Each of these sets is provided with color filters made up of sheets of colored gelatine. One set

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* *See the* RECORD, *June*, 1928, *page* 325.

has filters of an orange-red color which make the cells see things as the hypothetical red sensitive nerves of the retina see them; another set has yellow-green filters to give the green signal, and the third set has greenish-blue filters which perform a corresponding function for the blue constituent of vision. The scanning disc and the light source are the same as with the beam scanning arrangement used in monochromatic television. The only difference is in the photo-electric cells, and thanks to the tri-chromatic nature of color vision, it is only necessary to have three times the number of cells used previously to reproduce all colors. Three series of television signals, one for each set of cells, are generated instead of one and three channels are used for the transmission of the television signals.

The photo-electric cell container, or "cage," has been built in a somewhat different form from that used in our first demonstration. There three cells were used arranged in an inverted "U" in a plane in front of the object. In the new photo-cell cage twenty-four cells are employed, two with "blue" filters, eight with "green" filters, and fourteen with "red" filters. These numbers are so chosen with respect to the relative sensitiveness of the cells to different colors that the photo-electric signals are of about equal value for the three colors. The cells are placed in three banks, one bank in front of and above the position of the scanned object, one bank diagonally to the right, and another bank diagonally to the left, so that the cells receive light from both sides of the object and above. In placing the cells they are so distributed by color as to give no predominance in any direction to any color. In addition large sheets of rough pressed glass are set up some distance in front of the cell containers so that the light reflected from the object to the cells is well diffused.

The television signals produced in the color sensitive photo-electric cells through the color filters are no different electrically from those used in monochromatic television. Three sets of amplifiers are required, one for each color, and three communication channels in place of one, but the com-



During transmission one sits in front of the apparatus and sees the large sheets of diffusing glass behind which are the color-sensitive photoelectric cells



Herbert E. Ives and A. L. Johnsrud adjusting the receiving apparatus of the color television apparatus

munication channels are exactly similar to those which were used with the same scanning disc before.

For color television the three images must be received in their appropriate colors, and viewed simultaneously and in superposition. The first problem was to find light sources which, like the neon lamp previously used, would respond with the requisite fidelity to the high-frequency signals of television, and at the same time give red, green, and blue light. With such lamps available a decision would have to be made as to how the three colors could best be combined to form a single image.

Several methods of reception are possible. For displaying the transmitted image to a large audience a grid* could be employed similar to that used for the earlier demonstration but it would consist of three parallel tubes instead of a single one.

Thus far the television images have been received in a manner similar essentially to our method for monochromatic television. The surface of a disc similar to that used at the sending end is viewed, and the light from the receiving lamp is focussed on the pupil of the observer's eye by suitable lenses. To combine the light of the three lamps, they are placed at some distance behind the scanning disc and two semi-transparent mirrors are set up at right angles to each other but each at 45° to the line of sight.



The disc and motor drive for the color television apparatus are the same as for monochromatic television. The mirror and colored filters are in the small box behind the disc. One of the water-cooled argon lamps appears above the motor

One lamp is then viewed directly through both mirrors and one lamp is

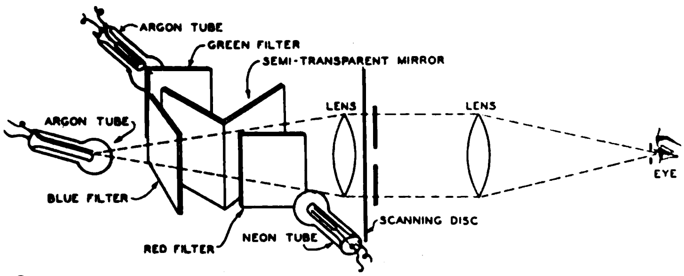
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* *See the* RECORD, *May*, 1927, *page* 329.

seen by reflection from each, as illustrated by the accompanying diagram.

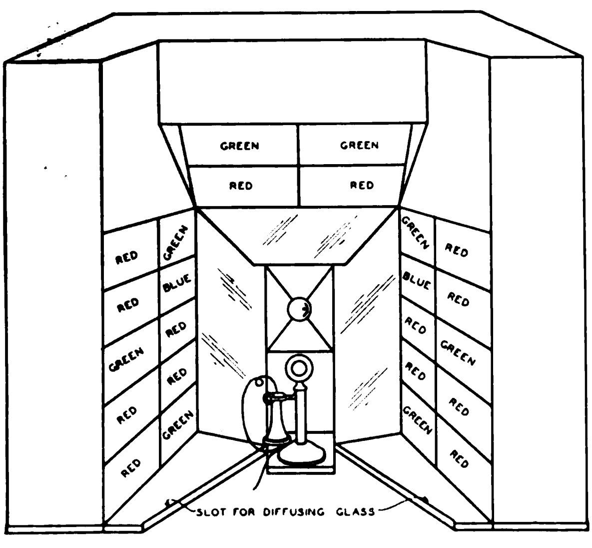
The matter of suitable lamps to provide the red, green, and blue light has required a great deal of study. There is no difficulty about the red light because the neon glow lamp which has been used previously in television can be transformed into a suitable red light by interposing a red filter. For the sources of green and blue light nothing nearly so efficient as the neon lamp was available. The decision finally made was to use another one of the noble gases—argon—which has a very considerable number of emission lines in the blue and green region of the spectrum. Two argon lamps are employed, one with a blue filter to transmit the blue lines and one with a green filter transparent to the green lines of its spectrum.

These argon lamps unfortunately are not nearly so bright as neon lamps and it was, therefore, necessary to use various expedients to increase their effective brilliancy. Special lamps to work at high current densities were constructed with long narrow and hollow cathodes so that streams of cold water could cool them. The cathode is viewed end-on. This greatly foreshortens the thin glowing layer of gas and thus increases its apparent brightness. Even so it is necessary to operate these lamps from a special "I" tube amplifier to obtain currents as high as 200 milliamperes.



One semi-transparent mirror reflects red light from the neon tube; one reflects green light from one argon tube; and through both mirrors passes blue light from the other argon tube

The receiving apparatus at present consists of one of the 16 inch television discs used in our earlier experimental work. Behind it are the three special lamps and a lens system which focusses the light into a small aperture in front of the disc. The observer looking into this aperture receives through each hole of the disc as it passes by, light from the three lamps—each controlled by its appropriate signal from the sending end. When the intensities of

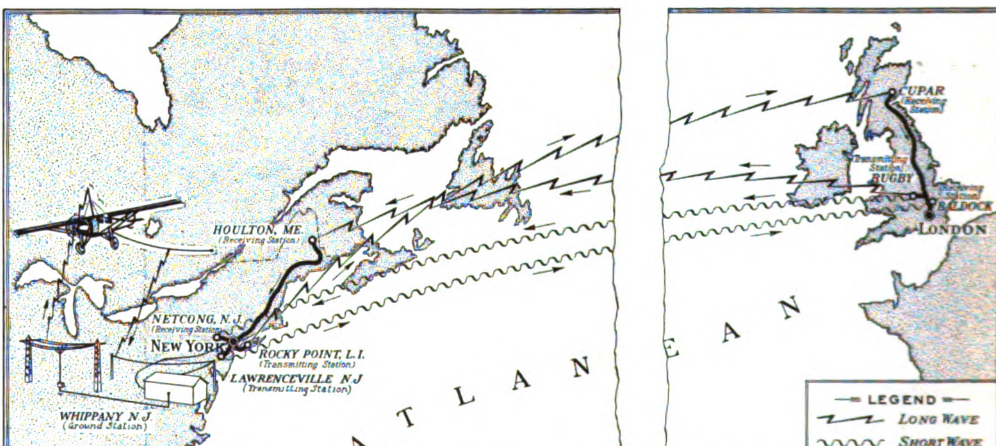


The grouping of the colored filters in front of the color-sensitive photoelectric cells is shown in this perspective sketch of the television transmitter

the three images are properly adjusted he therefore sees an image in its true colors, and with the general appearance of a small colored motion picture.

Satisfactory television in colors is a far more difficult task than is monochromatic television. Errors of quality which would pass unnoticed in an image of only one color may be fatal to true color reproduction where three such images are superimposed and viewed simultaneously. In three-color television any deviations from correct tone rendering throw out the balance of the colors so that while the three images might be adjusted to give certain colors properly, others would suffer from excess or deficiency of certain of the constituents. A further source of erroneous color exists at the scanning end. If the light from the object were not distributed equally to all the cells, the object would appear as if illuminated by lights of different colors shining on it from different directions.

Color television constitutes a definite further step in the solution of the many problems presented in the electrical communication of images. It is, however, obviously more expensive as well as more difficult than the earlier monochromatic form, involving extra communication channels as well as additional apparatus.



AIRPLANE TALKS TO LONDON

Demonstrating further the possibility of telephone conversations by wire and radio, a group of press association men flying in the Laboratories' airplane talked with their correspondents in London, on June 25. Flights were made from Hadley Field with A. R. Brooks as pilot and F. S. Bernhard as radioman. At Whippany, where the channel was transferred to and from wire lines, were F. M. Ryan, L. G. Young, and others of the radio development group. After passing to New York, the conversation was handled over the regular transatlantic circuits

Rotating the "Wax" for Sound Pictures

By L. A. ELMER
Apparatus Development Department

THE machine used in recording sounds on phonograph discs synchronously with associated pictures consists essentially of a turntable, bearing the "wax" and rotated by a synchronous motor* of constant speed, and an electrically driven stylus** cutting the record. In the design of this machine the primary aim is to ensure that the record is both faithful to the original sounds and synchronous with the pictures. Fidelity in the performance of the stylus would be vitiated by departures from uniformity in the speed of the turntable while sounds were being recorded or reproduced. Although a constant speed motor is used, its value would be destroyed if the machinery transmitting the drive from motor to turntable were not equally free of velocity variations. Thus the problem of fidelity involves not only the motor and the stylus but all the moving parts of the machine.***

Even were it possible to connect the motor directly to the turntable, casual variations in the speed would arise, from varying frictional loads on the turntable and bearings. But direct connection is unsatisfactory. Because the turntable must operate at a lower speed than the motor (one thirty-sixth of that speed), reducing gears must intervene. In the actual apparatus the motor drives (through a horizontal coupling) a worm engaging a worm wheel which drives (through a vertical coupling) the shaft to which the turntable is attached.

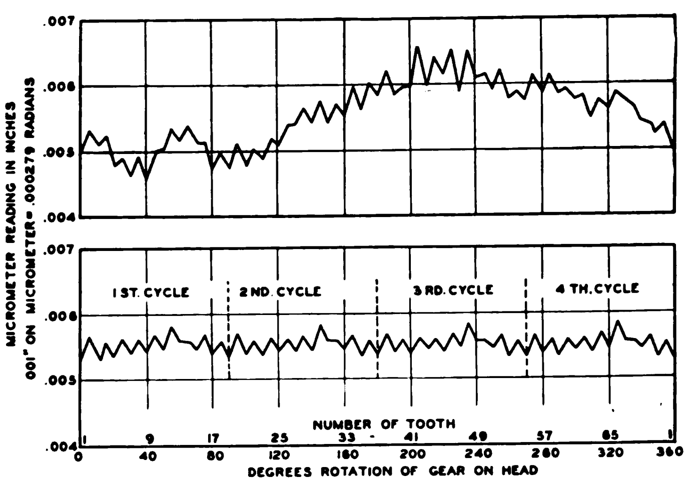


Fig. 1—*Above: difference between actual and correct positions of teeth on a typical gear, relative to an arbitrary reference position. Below: averaging effect of dividing same gear into four layers, calculated from data (above) for one layer*

It is cyclic speed-change that must be guarded against in this mechan-

* *H. M. Stoller,* RECORD, *November,* 1928.
** *H. A. Frederick,* RECORD, *November,* 1928.
*** *To be described in the Journal of the American Society of Mechanical Engineers this autumn.*



Fig. 2—The mechanical filter for turntable drive, as it appears in a commercial disc-recording installation

ism; all such changes with frequencies from about one-half cycle per second up to the higher limit of audibility are to be avoided. Speed changes at audible frequencies introduce extraneous sounds into the records, and speed changes at frequencies below the audible range produce changes in pitch. There are in general two points of origin for these variations: the turntable and its bearings, and the gears. Speed-changing variations in load on turntable and bearings are most likely to have the frequency of the rotation of the turntable (a little more than one-half cycle per second). From the gears three sorts of variation arise,—those accountable to inaccuracies in the spacing of the teeth (Figure 1), to errors in the shape of the teeth, and to the successive shifts of driving load from tooth to tooth. Together these may occasion variations with quite a range of frequencies.

The extent to which these variations are permissible is determined, for low-frequency changes, by the smallest change in pitch the ear will notice when pitch-variation is continuous. It appears that, when a pure tone is projected by a loud speaker of high quality, the ear can detect variations in its pitch which exceed one-tenth per cent of its frequency. This sets a severe requirement for constancy of rotation.

It is, furthermore, an overall requirement, for it applies to differences between the original and reproduced sound; and both a recording and a reproducing machine intervene between these sounds. Since both operate at the same speed, and since there is a high probability that the ultimate record will be lined up on the reproducer correspondingly to the "wax" on the recorder, variations in the speeds of the two are likely to be additive in their effects upon sound pitch. The sum of the variations permitted in the two, therefore, must not be greater than the total permissible variation for the system as a

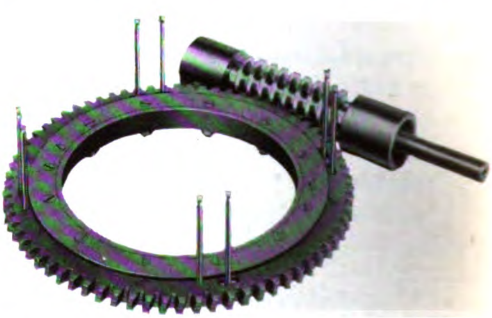


Fig. 3—The reduction gearing: a worm and a four-layer worm-wheel

whole. Since the more its velocity characteristics are made constant the more the apparatus costs, it is economical to be stringent in requirements for constancy in the recorder, of which comparatively few are manufactured, and more lenient in those requirements in the more numerous reproducers. An economical division between the two machines of the total allowable error appears to be in the ratio of one to four. The demand for constancy thus placed upon the recorder is far higher than can be met by gears and bearings of even the most careful construction. It is a demand which can be filled only by special means.

The fact that a continuous, slightly varying, motion of this sort is mechanically analogous to a slightly varying electric current helps to explain what these means are. A pulsating current can be treated as a direct current on which small alternating currents are superposed. The suppression of the alternating currents, to leave the unvarying direct current desired, can be accomplished by an electric-wave filter which attenuates the undesired alternating components. The electric filter consists of suitably

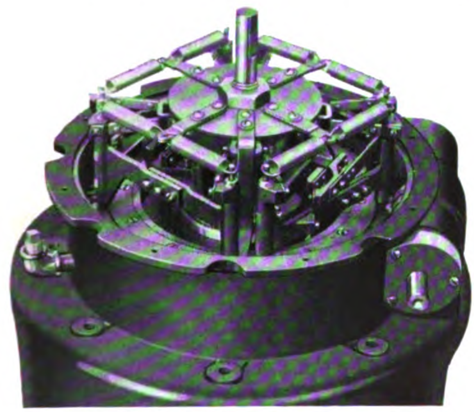


Fig. 4—The spring connection between gear and turntable shaft

interconnected coils, condensers, and resistances. Since mechanical analogs of these circuit elements are respectively to be found in masses, springs, and dissipative plastics, the mechan-

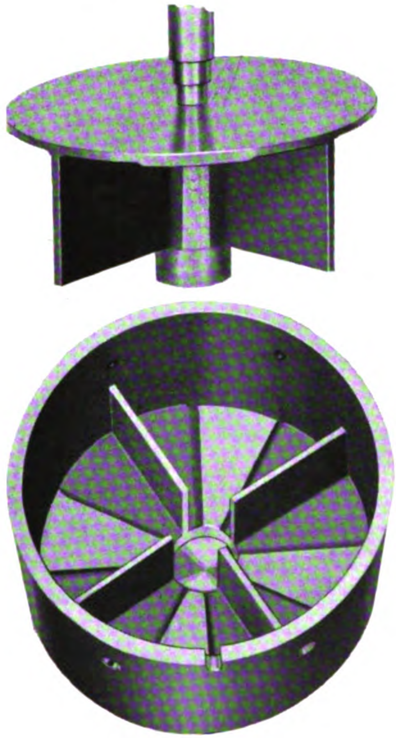


Fig. 5—The oil-damping connection between gear and turntable shaft. Above, oil cup; below, vane-bearing end of turntable shaft

ical-vibration filter can be visualized in terms of electrical principles.

Such a filter, designed in these Laboratories, is incorporated (Figure 2) in the Western Electric Company's commercial disc-recording apparatus. It uses coil-springs as its capacitances, viscous oil for its resistances, and the masses of its moving parts as its inductances. The great width of the frequency band to be attenuated, and the plurality of the sources of the varying-force, considerably complicate

the problem of determining what values of stiffness, weight, and dissipating ability should be used. For example, variations due to gear in-

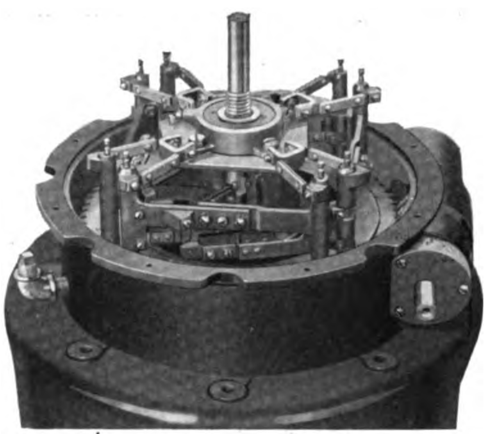


Fig. 6—Linkage mechanism and its braces, through which the gear drives the oil cup

accuracies are most readily absorbed by very flexible springs, whereas disturbances due to varying loads are best prevented from affecting turntable speed by the use of stiff springs. The filter finally designed embodies a compromise between these conflicting demands. Its general construction is such that the worm-driven gear drives the turntable shaft through the linearly flexible springs, and relative motion of the gear and shaft is damped by the oil.

The gear (Figure 3) is made in four layers. These layers are clamped together when the teeth are cut, and each layer is afterwards rotated ninety degrees relative to the adjacent layer. All are finally mounted, in engagement with the worn wheel, so that each can move independently of its companions. To each layer two cross-braced posts are rigidly attached, from the tops of which (Figure 4) springs lead to lugs on a plate fastened to the turntable shaft. Thus each layer of the gear independently drives the shaft through two springs. It is apparent that the offset four-layer structure of the gear divides by four the amplitudes of the disturbances caused by inaccuracies in the teeth, since at any one time, each affects but one of the four sets of springs. This structure also multiplies by four the frequencies with which these disturbances occur, since each inaccuracy in cutting is made to occur once for every 90 degrees, instead of once for every 360 degrees, of rotation. This higher frequency is far more readily absorbed by the filter than the lower would be.

The oil connection between gear and turntable shaft is effected by permitting the layer-gear to rotate a vane-bearing oil-filled cup, into which dip vanes attached to the turntable shaft (Figure 5). The mechanism

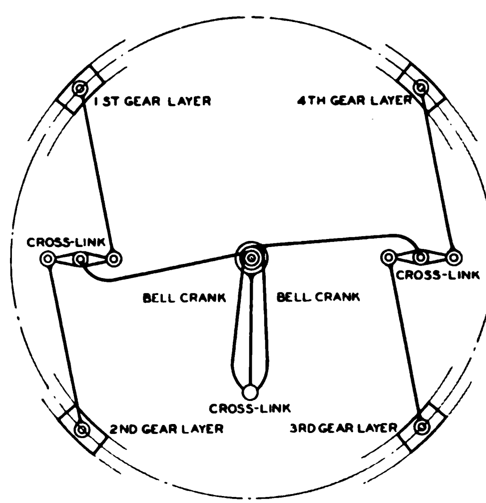


Fig. 7—Schematic diagram of linkage. The bell-cranks are pivoted at the center of the mechanism but are not attached to the shaft. The third cross-link, between the ends of the bell-cranks, is perpendicular to the plane of the diagram. From its center extends the only member which has a rigid connection at the center of the mechanism, to the collar which drives the oil cup

(Figure 6) through which the gear drives the cup is in this case rigid rather than elastic, but is again one whereby the effect of a gear irregularity upon the cup is quartered in amplitude and quadrupled in frequency. This mechanism is a system of links independently driven by each of the layers of the gear so as jointly to rotate the cup with their average velocity. To each layer, again through the perpendicular posts, is attached a link (Figure 7). The members of one and the other pair of these links are flexibly joined by cross-links, to the center of each of which is pivoted one end of a bell crank. The other ends of these two bell-cranks are in turn flexibly joined by a third cross-link, to whose center the member which drives the cup is attached. It is apparent that the motion of the center of each cross-link is the average of the motions of its two ends. Each of the first two cross-links, therefore, averages the motions of two of the gear-layers, and the third cross-link averages the motions of the first two cross-links, driving the oil cup with the average motion of all four gear-layers.

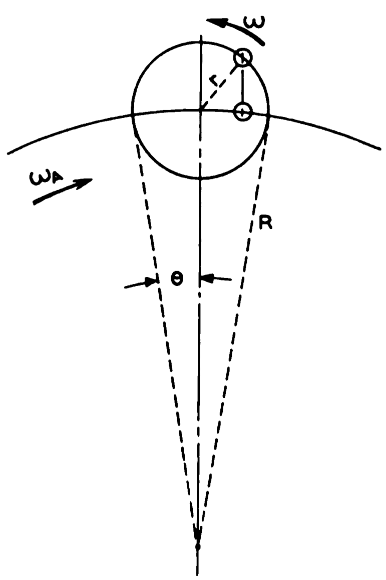


Fig. 8—Steps in the development of the linkage, showing its successively more rugged construction

Because the deflections with which this apparatus is expected to operate are very small, it is essential that no motion be lost by "backlash" in pivots. For this reason, and to minimize pivotal friction, flat reed-springs are used for all joints. Since the linkage cannot be constructed in a single horizontal plane but must be built in several planes, it is subject to warping forces which tend to produce velocity errors. To avoid these, the linkage is extensively braced (Figure 8).

In the development of this filter, reliance upon theory had to be supplemented by measurements of the effectiveness of various models. Since smooth rotation of the turntable was in view, fluctuation in turntable speed was the performance to be directly measured. This was accomplished stroboscopically. On the rim of the turntable 216 accurately spaced groves were cut. A disc, with six radial slots, was connected by a rigid drive to the shaft of the synchronous motor. The disc was so placed that the grooves on the rotating turntable could be observed one by one by a microscope looking through the slots in the rotating disc. Observed through this apparatus, the groove on the edge of the rim appears to stand still when the speed of the turntable is exactly one thirty-sixth the speed of the motor. A small error in turntable speed causes the image of the groove to change position momentarily. The amount of this shift can be read in thousandths of an inch on a filar micrometer placed in the eyepiece of the microscope. From this reading the percent velocity variation can be calculated (Figure 9).

The model finally developed drives the turntable with remarkable constancy. Of the velocity variations from the two major sources of error — from varying loads, at one cycle per revolution, and from varying gear-spacing, at four cycles per revolution — the former has been reduced to 0.04 per cent and the latter to a point below the limit of measurement. Supplemented by suitably modeled drives for reproducing machines, recording drives of this type provide ample insurance against maltreatment of sounds by driving machinery.



ω_A = Av. Turntable Vel.

$\omega_A + \frac{\omega r}{R}$ = Max. Turntable Vel.

$\omega_A - \frac{\omega r}{R}$ = Min. Turntable Vel.

ω = Angular Velocity of Vibration $= 2\pi f$.

$2\frac{\omega r}{R}$ = Velocity Variation

$200\frac{\omega r}{\omega_A R}$ = Velocity Var. in per cent.

$$200\frac{\omega r}{\omega_A R} = 200\frac{\omega}{\omega_A}\theta$$

θ = Amplitude in Radians

When $\frac{\omega}{\omega_A} = 1, \qquad 200\frac{\omega r}{\omega_A R} = 200\,\theta$

Fig. 9—Method of converting stroboscope micrometer reading to per cent velocity variation. The curve of large radius represents the rim of the turntable, and the curve of small radius represents the familiar diagram of harmonic motion. At the projection of the end of the small circle's radius is a groove on the turntable rim. The quantity read on the micrometer is 2r,—the maximum motion of a groove

A Carrier Telephone System for Power Lines

By C. F. BOECK
Apparatus Development Department

IN the operation of a system for generating and distributing electric power, dependable communication between the power stations is an essential requirement. The necessary communication facilities can usually be obtained to advantage from the local telephone company. In certain cases, however, the power plants are in such inaccessible and unpopulated communities that the telephone company's facilities are not readily available. The power plants may be widely separated, perhaps hundreds of miles from the community to which current is supplied. The costs involved in constructing a separate telephone circuit may be excessive. Under such circumstances, the strongest and probably the most direct physical link connecting the stations with the power system is made up of the power wires themselves. Their size, and the towers on which they are supported make them proof against any conditions but the most severe, and offer a dependable communication path.



Such a situation confronted the Pacific Gas and Electric Company, which supplies much of the electric power for San Francisco and the neighboring communities. Most of this power is generated at hydro-electric stations more than 200 miles away, in the northern part of California, and it is transmitted for about 200 miles of the distance by a 220,000-volt line built on a cleared right-of-way largely over mountains and heavily wooded country. The Electric Company had built a private telephone line on a separate right-of-way, but this was of course subject to damage by heavy storms. It was decided therefore to use the power transmission wires as a communication channel, and equipment for telephone service by carrier current was therefore installed. Facilities were provided for communication between the load dispatcher at Oakland, who directs operation of the system, and the operators at the Claremont and Vaca-Dixon distributing stations and the Pit River No. 1 generating station.

Systems for telephone conversations over power lines by carrier current are not new; the first one installed by Western Electric was for the Georgia Railway and Power Company, in 1924, and others have been constructed and installed since, for power companies throughout the country. Carrier telephone systems have also been made by other electrical manufacturers. Since the Georgia in-



Fig. 1—Pit River Power Station No. 1 of the Pacific Gas and Electric Company

stallation, the Western Electric systems have profited from the course of development taken by carrier systems for use on telephone circuits, and have been redesigned from time to time, as development work opened the way to improvements. Marking the greatest advance to date is the recently designed system which had its first commercial application in the installation for the Pacific Gas and Electric Company.

To this system is given the full descriptive title, "carrier suppressed, single side-band, single frequency, duplex, power line carrier telephone system." The carrier current itself is not transmitted, and only one of the side-bands resulting from modulation by the voice currents is transmitted. Duplex service is offered—that is, speech is transmitted in both directions, with current of the same frequency. In addition, modulation and demodulation take place in two stages, but since that circumstance does not describe the traffic possibilities directly, it is not mentioned in the title.

The general plan of operation is shown in Figure 2, which gives a block schematic of the principal equipment at any one terminal. For connecting with the power line, the same coupling equipment is used jointly for messages in both directions. Likewise, unless separate circuits are installed from the telephone transmitter to the transmitting equipment and from the receiving equipment to the telephone receiver, there must be a

circuit which will segregate outward and inward messages passing over it. Otherwise the received and demodulated currents would pass directly to the transmitting equipment, and would continue in a closed loop through transmitting and receiving equipment. The separating circuit, known as the voice-frequency hybrid circuit, is the point at which the outgoing currents meet the terminal equipment, and the received currents leave it.

Between the hybrid circuit and the coupling circuit outgoing and incoming currents pass over separate paths. From the hybrid circuit, the currents to be transmitted go to the duplex control circuit, which determines the direction in which the terminal equipment operates at any moment. The transmitting circuit is normally inactive and the receiving circuit active. While a user speaks at the transmitter, however, the duplex control circuit reverses this situation, putting the transmitting circuit into active operation and making the receiving circuit inactive.

The modulating and demodulating circuits are separate, and each deals with currents passing in one direction only. Since carrier current of the same frequency is used for transmission in both directions, the oscillators and certain of the auxiliary pieces of apparatus are common to both the transmitting and receiving circuits.

When the system is in use, voice currents from the telephone instrument go first to the hybrid circuit, whence they are impressed jointly on the first modulator and the duplex control circuit. In response, the latter raises the grid bias of the tubes in the receiving equipment sufficiently to stop operation, and after a delay of a few thousandths of a second lowers to normal the grid bias of a pair of tubes in the transmitting equipment. Thus the receiving equipment is shut off and the transmitting equipment made active for the duration of the outgoing voice message, with an intervening delay to prevent momentary access to the receiving equipment by the modulated currents to be transmitted. The first modulator is of the well-known "push-pull" type; there the voice currents are impressed on a carrier wave of 28,600 cycles. At the next element, the modulator band-pass filter, the carrier leak and upper sideband are both suppressed, and the lower sideband is transmitted to the second modulator, which is also of "push-pull" design. The carrier frequency supplied to it can be varied through the range of 70,000 to 170,000 cycles, and the tuned circuits involved can be adjusted correspondingly, so that the sideband to be transmitted can be

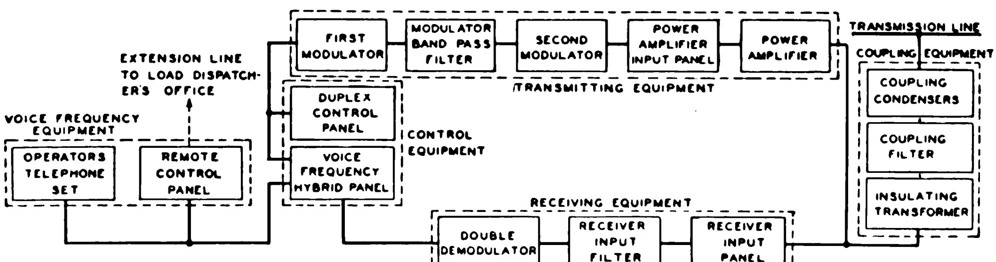


Fig 2—Block schematic of the carrier system

placed anywhere in the range suitable for power-line-carrier transmission—50,000 to 150,000 cycles. In the second modulator there are produced two sidebands which, since the modulating currents form a band between the frequencies of 26,100 cycles to 28,400 cycles, are some 50,000 cycles apart and can be separated by comparatively simple discriminating networks. The separation takes place at a double-tuned transformer joining the second modulator and the power amplifier. In addition to acting as output transformer for the modulator

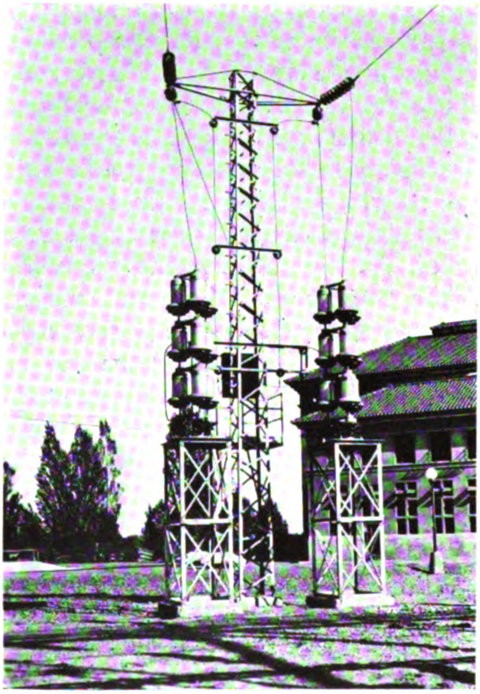


Fig. 3—Coupling condensers for 110,000 *volt lines*

and input transformer for the amplifier, this member is effectively an adjustable band-pass filter readily adjustable to transmit a band 2500 cycles wide anywhere in the range from 50,000 to 150,000 cycles. The adjustment is correlated with that of the oscillator of the second modulator, so that only the lower band is allowed to pass through to the power amplifier. There its power is raised to 100 watts.

At that point the modulation and amplification are over, and the current is ready to be impressed upon the power line, through the coupling equipment. First it passes to the insulating transformer, whose functions are to prevent unbalancing of the circuit and, by virtue of the insulation, to give additional protection to the equipment. This transformer is the point of contact between the terminal equipment, in which one of the wires is grounded, and the leads to the power line, which are balanced electrically around a ground connection at the mid-point of a drainage coil which is part of the coupling filter. Then the current goes to the coupling filter. In addition to acting as a filter to suppress currents outside of the frequency band wanted, this member drains from the leads the 60-cycle current transmitted to them through the condensers; providing a low resistance path to ground for this current, it keeps down the voltage in the leads. The last step taken by the current is to the coupling condensers which are the actual point of contact with the power line.

When the speaker is finished, the duplex control panel blocks the transmitting circuits and simultaneously places the receiving circuits into active operation. Then the response from the distant station, reaching the coupling equipment, passes in order through coupling condensers, coupling filter and insulating transformer, and is made ready for demodulation. First it is impressed upon the receiver input circuit, by which its power level

is adjusted for the subsequent equipment. Then comes the receiver input filter which, like the coupling filter, attenuates accidental currents of other frequencies; it is an adjustable band-pass filter having the same range as the coupling filter. Passing that point, the high-frequency currents are impressed upon the demodulator, where they are translated in two steps to their original voice frequencies. The two carrier frequencies are the same as those used in modulation, and they are supplied by the same oscillators, but the steps take place in reverse order. Hence the intermediate currents, after the first stage of demodulation, are of the same frequency as the outgoing currents between the first and second modulators.

Signalling is accomplished with pulses of 1600-cycle current, supplied to the first modulator of the calling terminal and progressing from there to the transmission line just as would voice currents. At the other terminals of the system, the incoming signals pass through the receiving equipment and are restored to their original 1600-cycle frequency by double demodulation. Thereupon they go to the signal-receiving circuit, not shown in the block schematic. This is a branch from the main receiving circuit, to which go part of the incoming currents after demodulation, as long as the receiver remains on the switchhook. The currents are amplified and rectified, and in the plate circuit of the rectifier operate a relay controlling a train-despatching selector which responds only to a predetermined combination of signal pulses. Thereupon signal current is connected at the station, to indicate that a call is waiting. As soon as the receiver is removed from the switchhook however the signal-receiving circuit is disconnected.

Like most other telephone systems, a system using carrier current on a power line must give duplex service — that is, it must transmit speech in both

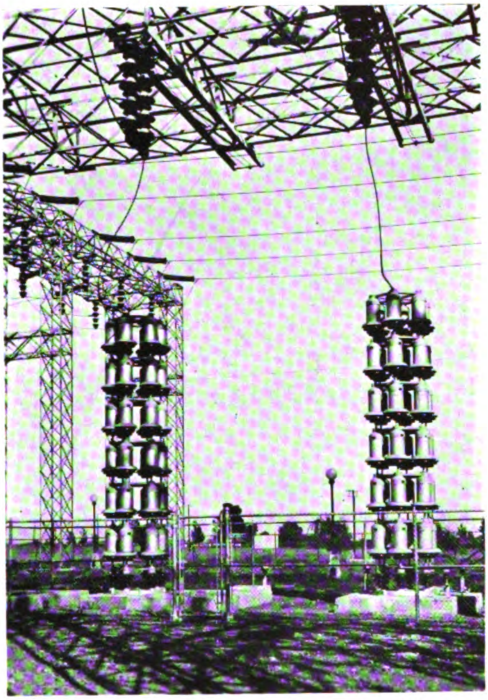


Fig. 4—Coupling condensers for 220,000 volt lines

directions. Carrier telephone systems on communication lines ordinarily use separate frequency ranges for the two directions. This power line carrier system, however, on account of the characteristics of the power lines, was designed to transmit currents in both directions with the same modulating frequency. Most power lines are marked by wide discrepancies in their transmission-characteristic curve, with peaks and valleys only a few kilocycles apart. At the present state of development, it is usually difficult to predict accurately the best frequency range

for conversation over a particular network of power lines. On that account it is necessary to design equipment readily adjustable to the most suitable range at any particular installation. Accordingly a single-frequency system is more flexible, and can be more readily installed on a complex network of power lines, since a single usable frequency range can be located more readily than can two. In certain cases, furthermore, several carrier channels may be wanted on a single transmission line particularly when that line connects two or more power systems. Where each channel uses a single band of frequencies, satisfactory spaces can be found for additional channels which might already be occupied were two bands to be needed for each.

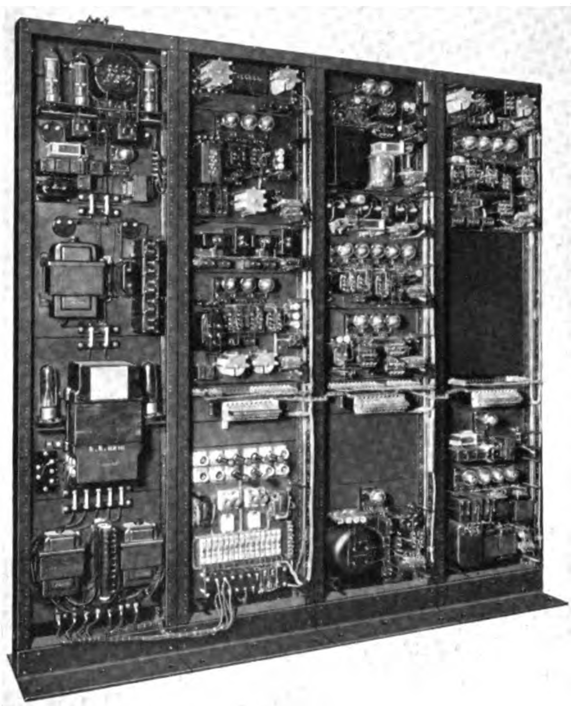


Fig. 5—*Terminal equipment—rear view*

Although both sidebands produced by modulation and the carrier current itself could be transmitted, it is sufficient to transmit one of the sidebands only and to supply current of the carrier frequency, at the receiving station. With the latter arrangement, a band of frequencies only 2500 cycles wide need be transmitted, whereas for reproduction of the same quality a band of at least 5000 cycles must be transmitted when both sidebands are used. On account of the irregular transmission characteristics of most power lines, it is difficult and sometimes impossible to find a band 5000 cycles wide, over which transmission is uniform. Satisfactory bands of half the width are much more numerous, and the variation in transmission throughout their range is ordinarily considerably less.

Just as a single-frequency system requires half the frequency space of a two-frequency system, a single-sideband system uses about half the space of a two-sideband system. That advantage is of course valuable on power lines where several telephone channels are wanted. Such demand for several channels has however been somewhat limited so far.

In demodulating circuits of the type used in this equipment, loudness of the received speech depends on the amplitude of the carrier and that of the sideband. In this system, therefore, the loudness is less affected by changes of the transmission loss of the line than in any system where the carrier is transmitted. In that case, carrier as well as sideband **undergo**

variable attenuation whereas here the carrier frequency is produced for demodulation at the receiving end and its amplitude is independent of transmission conditions on the intervening power line.

Likewise the system has a greater effective transmitting range than any carrier-transmitted system which delivers the same high-frequency power to the transmission line. The carrier current, produced at the receiving end, is of course not attenuated by the line, and the sideband current makes up all of the current delivered to the line, rather than only a third of it as in carrier-transmitted systems. Attenuation of the sideband current may therefore be much greater than in a carrier-transmitted system if the received speech in the two is to be of the same loudness.

By adoption of double modulation, the necessary band-pass filters have been greatly simplified. Such filters are used on all the long distance telephone circuits operated with carrier currents, but they would become extremely complicated if their frequency range were to be raised to any value likely to be used for a power-line system. Were it desired to separate the upper and lower sidebands of a 30,000 cycle current modulated by currents from 0 to 2000 cycles, it would be quite feasible to build filters passing respectively the bands from 28,000 to 30,000 cycles, and from 30,000 to 32,000 cycles. Were the carrier frequency 100,000 cycles however, it would be both difficult and expensive to build either fixed or adjustable filters to distinguish between the bands of 98,000 to 100,000 cycles, and 100,000 to 102,000 cycles. With upper and lower sidebands from the second modulator more than 50,000 cycles apart, the function of separation is comparatively simple and networks are used which are readily adjustable should any changes be wanted in the carrier frequency.

The equipment is mounted on standard relay racks, with the various circuit elements built upon individual panels. In conformity with power-plant practice, all tubes and other apparatus are mounted on the rear of the panels, with only the control and meters appearing on the front.

There are four bays at each terminal in all, shown in Figure 6. On the left is the receiving bay, with the receiving equipment and the rectifier which supplies plate voltage for the

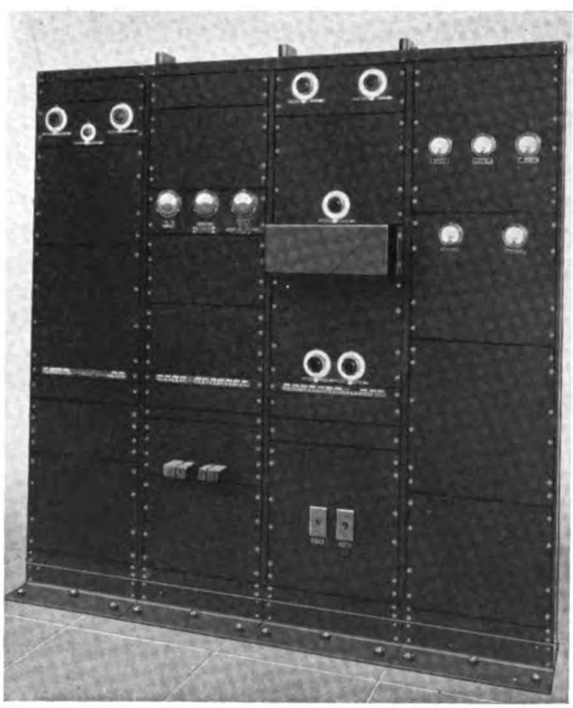


Fig. 6—Terminal equipment—front view

low-power vacuum tubes. Next is the signalling bay, on which are mounted the signalling circuit, the duplex control circuits, and extension equipment which makes it possible to control the terminal from a remote station. On the third bay, the transmitter bay, are mounted the two modulators, the band-pass filter which connects them, and a control panel for power supply. The bay on the right is called the power amplifier bay, and on it are mounted the power amplifier and the associated circuits for current supply.

Ship-to-Shore Telephone Service

The project of extending telephone service to ships at sea, upon which experiments were conducted some years ago, is being actively taken up anew, with the expectation of offering to the public commercial ship-to-shore telephone service. Arrangements are being made to construct shore receiving and transmitting stations in New Jersey, suitable for handling a general service along the transatlantic steamship lanes and for the installation of a laboratory model transmitter and receiver aboard the S.S. "Leviathan." Pending the completion of the commercial shore transmitting station, and during the initial engineering tests, transmission will be carried out from the Deal Beach experimental station.

Eight radio channels have been assigned by the Federal Radio Commission for experimental work; their carrier-frequencies range from 1608 *kilocycles to* 17,300 *kilocycles. Since the course of transatlantic vessels is along fairly well-defined routes, directive antennas will be used. It is planned to install in the shore station the same equipment as is used at the Lawrenceville and Netcong transatlantic stations.*

Capability Engineering of Step-by-Step Relays

By F. H. HIBBARD
Apparatus Development Department

WHAT a piece of apparatus or equipment is capable of doing is often easy to determine. It may have been designed for only one thing and perhaps is capable of nothing else. There are, however, pieces of equipment that, with slight rearrangement of their parts, can perform many different operations. Here a prediction of capability is not so easy and capability engineering may be defined as the preparation of such complete data regarding the characteristics of an apparatus as to provide for its future application to a large number of new and different uses with a minimum of engineering effort. This engineering in advance for any future relay of the step-by-step type has provided an interesting problem for the relay design engineers.

The step-by-step relay may be termed the "Erector Set" of the circuit designer's play room equipment. It includes fourteen different magnet assemblies and six different thicknesses and three different shapes of contact spring. The magnet assemblies each have the same size of core and spoolhead, but may be equipped with different lengths of copper slug or sleeve, and any of a number of windings can be applied to the magnets. The contact springs, shown in the accompanying illustration, may be assembled with a single standard thickness of insulator (except in a few special cases where a second thickness is required) to form various contact arrangements such as a make or break pair, or three springs in a break-make or make-before-break combination. Any number of these arrangements may be combined in a single pile of springs up to

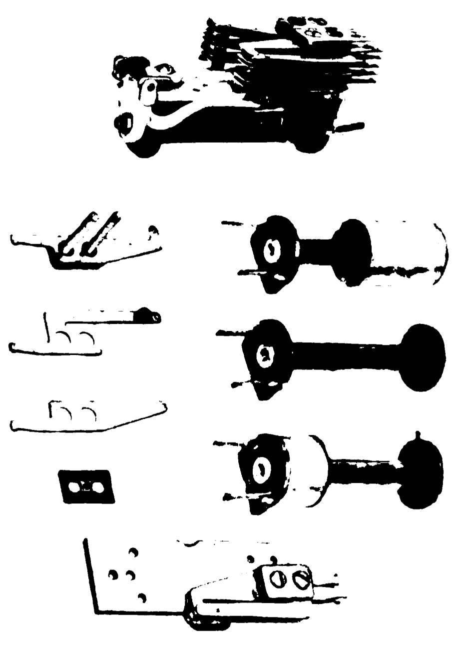


Fig. 1—*The elements from which an indefinite number of step-by-step relays may be built up are here shown both individually and assembled into a typical relay*

a possible maximum of fourteen springs, and two such contact assemblies can, if necessary, be mounted on and operated by one relay.

Omission of the usual insulating

bushing for the clamping screw of the assembly contributes to uniformity in assembly. The flat micarta insulators of the spring pileup have two embossings or upsets whose diameters fit the clamping holes in the contact

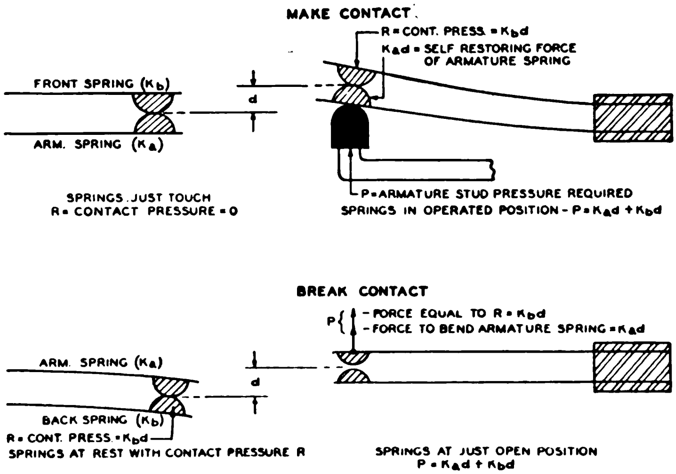


Fig. 2—Forces required to make normally open contacts, or to break normally closed ones are here shown diagrammatically. The additional force required to move the armature spring through a given gap separation is not indicated

springs. The screw holes in the insulator are drilled in the centers of these embossings so that contact between the screw and spring is prevented by the embossing which registers in the hole of the spring. With the use of an adjustable "non-freeze" stop, in the form of a brass screw in the armature, it is apparent that the assembly of this type of relay requires little effort beyond the proper selection of magnet and springs. To determine in advance, however, that any relay so assembled will function satisfactorily under specified circuit conditions, requires an engineering study of capability.

The engineering of a relay as an ordinary circuit element may be simply stated as follows. The necessary switching functions require a number of contact springs which must be moved to make or break certain contacts. The magnet is connected in a circuit whose electrical constants determine the amount of current which will flow in the winding. Size and heating limitations of the magnet spool determine the ampere turns which can be obtained with this current, and the magnetic pull resulting from these ampere turns must be sufficient to move the contact springs to make or break the required contact pressures. Although several additional and more complicated relations have to be considered in relay engineering, the foregoing indicates the necessity of providing two basic classes of information if the operation of various combinations of magnet and springs is to be predetermined. Capability data for this apparatus must, therefore, provide: (a), the pull to be obtained with any possible winding of any proposed magnet; and (b), the force required to move satisfactorily any proposed combination of contact springs.

Data applying to the magnetic pull of the different coils used are obtained by direct experiment, and presented for use in curve form. Laboratory observations are made of the pull resulting from various ampere turns for various gaps between the armature and core for each of the coils used,

and families of curves are plotted to show, within the possible working range, the minimum pull which may be expected with any value of applied ampere turns at any core gap. By reference to earlier work in capability engineering, giving the standard winding constants and methods of calculation, it is possible to discover the available ampere turns for any magnet in any proposed circuit, and thus to predetermine, by means of the curves, the pull in grams to be obtained from any proposed magnet.

Having thus examined the horse, the cart—or the load which the magnet must pull, next requires consideration. Although the total travel of the relay armature is less than 1/32″ (only .025″ perhaps, measured at the center of the core), several load changes occur during the travel as one spring after another is picked up. Since the pull of the magnet also changes during armature travel, rising at a steadily increasing rate from a very low value at the start to a relatively high value at the end, it is evident that, to forecast the successful operation of the relay not only the force required to make or break each contact of the assembly, but also the distribution of load in the armature stroke, must be predetermined. In terms of graphic analysis then, it is necessary to draw the load curve of any proposed contact assembly, and to compare it with the pull curve of the magnet with which it is to operate.

The fundamental requirements of contact pressure and contact separation serve as the basis of load curve determination. Since pressure at the contact is proportional to the spring deflection, a given contact pressure is, therefore, a measure of the deflection of the back spring of a break contact or of the front spring of a make contact. Added to this deflection or "follow," the contact separation defines the necessary motion of the springs which are directly carried by the armature. Determination of load value for the operation of any contact pair is therefore readily made as illustrated in Figure 2, when the load constants, or grams per .001″ deflection required, are known for the individual springs. These constants, Ka for the spring armature and Kb for the back spring, have been measured in the laboratory and tabulated for each shape and thickness of spring used, and these data alone would suffice for load curve prediction in the simple case illustrated in which the armature stud is applied in line with the contact.

In the actual contact assembly of this relay, however, the armature

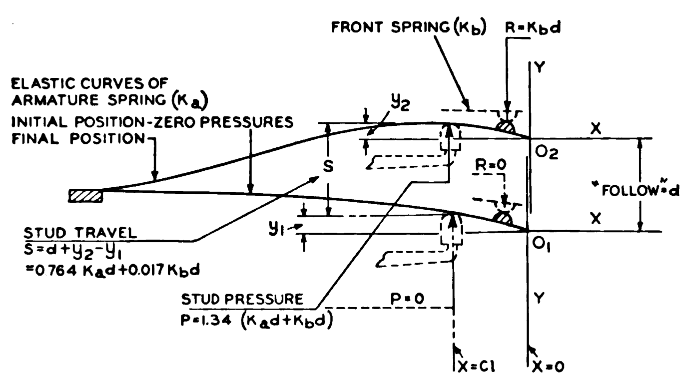


Fig. 3—Applying the operating force at a point between the contact and the fixed mounting, changes both the force that must be applied and the distance that the stud must travel

stud is applied to the springs as shown in Figure 3, and not in line with the contact. This introduces obvious difficulties in applying the simple reasoning of Figure 2. The motion at the stud may be materially different from the motion of the contact, due to the bending of the light armature spring about the stud. Also the force required at the stud is, of course, greater than that required at the contact for any given contact motion. It is convenient to use the elastic theory presented in standard textbooks which is commonly applied to the design of steel members in structural engineering. Solutions under this theory give workable values of force and travel required at the stud to produce any given contact pressure in terms of the build-up constants Ka and Kb of any individual contact springs. Although the relations in this case are more complex, it is possible to obtain from the elastic curve solutions a value of load constant, or grams per mil of travel or deflection at the stud, required for the operation of any contact group; and also the travel at the stud per gram of contact pressure at the contact.

To determine the distribution of load for the several contacts of the assembly throughout the armature stroke, and thus to predetermine a complete load curve, reference is made to the adjustment requirements for the relay which is schematically illustrated in the upper part of Figure 4. In the schematic, the core gap at the make or break of each contact pair is indicated by values in inches written between the springs. By this, the beginning or end of the "in-contact" travel of each set of springs is known. Hence it can be determined which pairs are moving "in-contact" and which armature springs are moving alone, at each point in the armature travel. It is then a simple matter to total the load resulting at any point in the armature travel and thus predict the complete load curve. From this the necessary ampere turns for operation or non-operation of the relay are determined by

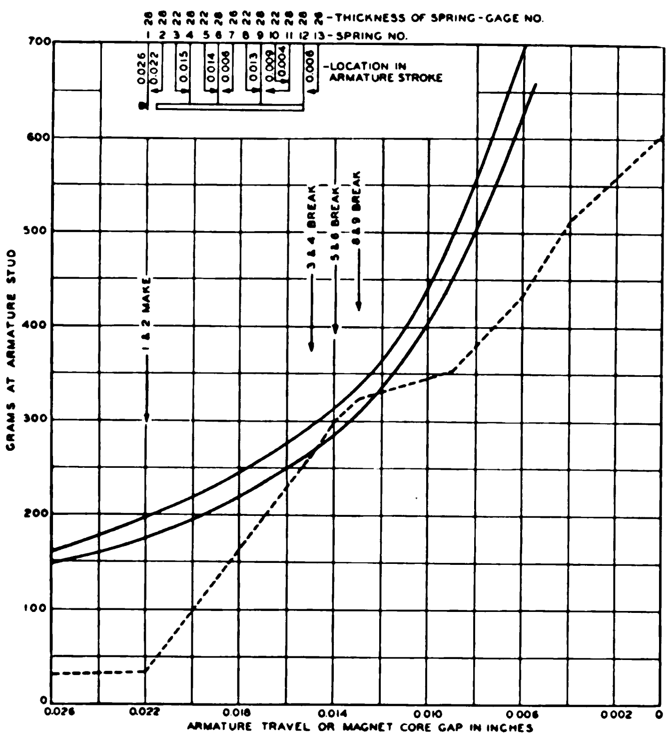


Fig. 4—By superimposing pull curves for different ampere-turns (solid lines) on the load curves (dotted) the proper winding to operate is determined

routine calculation. Previously it was necessary in each case to make an experimental determination of the load and ampere turns on an especially assembled and adjusted model.

As an illustration of the load curve and magnet pull curve comparison above described, the curves in Figure 4 have been prepared by G. B. Baker. These show a comparison of computed load on the large spring assembly schematically shown above the curves In actual application of course, the complete plotting of these curves is unnecessary. In actual application the ampere-turn determinations for operation are made by comparison of the progressive computed values of the load at each make or break point with the predetermined pull values of the coil at the corresponding core gaps.

The load and travel constants above referred to are obtained by formulae containing the stiffness constant of the individual springs which were computed from the results of laboratory load-deflection tests. This method, therefore, provides a ready means for determining the effect of any spring thickness or stiffness since the load curve can be recomputed with any values assigned, and limiting conditions can thus be introduced far more readily than could be done experimentally.

Sufficiently complete and general characteristics of the elements of the design have been obtained and tabulated to enable one to predict the operation of any anticipated arrangement of standard parts. These data have been arranged, and a method of use devised which involves a minimum of engineering effort; in recurrent application of these results to the solution of relay problems. This provides not only a systematic method of engineering relays to meet new circuit conditions but also a convenient means of checking the adequacy of relays employed in existing circuits.

The Policy of the Bell System

A reprint of part of an address delivered by Walter S. Gifford in Dallas before the National Association of Railroad and Utilities Commissioners*

There are today** over 420,000 stockholders of the American Telephone and Telegraph Company and no one of them owns as much as one per cent of the capital stock. The business of this Company and its Associated Bell Telephone Companies, whose common stock is largely owned by this Company, is to furnish telephone service to the nation. This business from its very nature is carried on without competition in the usual sense.

These facts have a most important bearing on the policy that must be followed by the management if it lives up to its responsibilities. The fact that the ownership is so widespread and diffused imposes an unusual obligation on the management to see to it that the savings of these hundreds of thousands of people are secure and remain so. The fact that the responsibility for such a large part of the entire telephone service of the country rests solely upon this Company and its Associated Companies also imposes on the management an unusual obligation to the public to see to it that the service shall at all times be adequate, dependable and satisfactory to the user. Obviously, the only sound policy that will meet these obligations is to continue to furnish the best possible telephone service at the lowest cost consistent with financial safety. This policy is bound to succeed in the long run and there is no justification for acting otherwise than for the long run.

It follows that there is not only no incentive but it would be contrary to sound policy for the management to earn speculative or large profits for distribution as "melons" or extra dividends. On the other hand, payments to stockholders limited to reasonable regular dividends with their right, as the business requires new money from time to time, to make further investments on favorable terms, are to the interest both of the telephone users and of the stockholders.

Earnings must be sufficient to assure the best possible telephone service at all times and to assure the continued financial integrity of the business. Earnings that are less than adequate must result in telephone service that is something less than the best possible. Earnings in excess of these requirements must either be spent for the enlargement and improvement of the service furnished or the rates charged for the service must be reduced. This is fundamental in the policy of the management.

The margin of safety in earnings is only a small percentage of the rate charged for service, but that we may carry out our ideals and aims it is essential that this margin be kept adequate. Cutting it too close can only result in the long run in deterioration of service while the temporary financial benefit to the telephone user would be practically negligible.

Our policy and purpose are the same as yours—the most telephone service and the best, at the least cost to the public. Without overlooking the fact that we lack the big money incentive for maximum profits and the drive for improvement that results from active and strong competition, we believe the telephone company is organized to make continuous and effective progress. . . . We shall continue to go forward, providing a telephone service for the nation more and more free from imperfections, errors or delays, and always at a cost as low as is consistent with financial safety.

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* *Printed in full in* BELL LABORATORIES RECORD, *December*, 1927, *page* 101.

** *October*, 1927. *At the present time the number is about* 450,000.

Vice-President Page Addresses the Laboratories

ARTHUR W. PAGE, Vice-President of the American Telephone and Telegraph Company in charge of public relations, talked on June 13 in our auditorium before the men and women supervising the work of the Laboratories. Introduced by Vice-President Charlesworth, Mr. Page extended President Gifford's outline of Bell System policy, delivered here two months ago, by discussing the problems attending the interpretation of that policy to the public which the System serves.

First pointing out the System's place in economic society, Mr. Page described the texture of services of which our civilization is composed, distinguishing between those performed by the entire public through its government, and by groups of the public. The interests of the public as a whole in most of the latter services are protected by competition among the several groups performing them, but in some cases the performance of a service is entrusted to one group and is guided in the public interest by regulation. Telephone service is so entrusted; and the Bell System, because of the large number of telephones and long lines which it operates, accepts this trust as a national responsibility.

With President Gifford's statement of Bell System policy in relation to this trust—to provide the most telephone service and the best at the least cost to the public—probably none would cavil; nor would any disagree that its familiarity with telephony should enable the System to find constantly improved ways of fulfilling that policy. But there is an embracing and historically natural suspicion toward the fidelity of all monopolies, a part of which, because of its national and thus monopolistic character, is directed toward the Bell System. Hence there is occasional disposition to question that the System actually means what it says in its statements of policy. As Mr. Page pointed out, the System's nature and deeds offer direct answers to such natural distrusts.

There is first a presumption that it is to the System's financial advantage not to follow its expressed policy—that it wishes to make more money than strict adherence to that policy would permit. The System's rejoinders to this suspicion are its promise and history of paying its owners only a reasonable and regular dividend, adequate to attract the necessary capital; of providing the stockholders with opportunities for further investment in the business from time to time; and of turning the surplus back into the service. In thus making the public the residuary legatee of its efforts, the System has been even more generous to it than law or regulation has so far seen fit to ask.

The System's financial behavior is to the public advantage not only directly in this way, but also indirectly,

by the elimination of capital waste. Organized in an era of exploitation which was characterized by the gain and loss of great individual fortunes, the System has uniquely made no great fortunes and lost money for no one. Its growth has been reasonable and steady, again as a result of conscious policy. Its composite owner, the 450,000 stockholders, unlimited in resource, do not die or retire at any one time, nor press a personal whim interfering with far-reaching programs which look to the continuous reduction of rates.

A notion also obtains that monopoly breeds slothfulness, inefficiency and arrogance. The public demands, for a rebuttal of these accusations, evidence of energetic efforts to bring to everyone the benefits whose provision has been entrusted to the monopoly, and to refine and improve the service. The System's activity in the former respect is embodied in its nation-wide sales program, reaching every element of the public with information regarding those services offered by the System which best suit particular needs. Insurance of progress and efficiency has been provided by setting up organizations exclusively devoted to the improvement of the System's procedures. It is in this capacity that the Laboratories plays its important part.

In the achievement of these ideals of operation in the public interest, monopolies can more swiftly and adequately progress without, than with, the restraints of external control, so long as the monopolies hold these ideals in good faith. Mr. Hoover, when Secretary of Commerce, enunciated this, and epitomized the attendant problems in the words, "The thing we all need searchingly to consider is the practical question of the method by which the business world can develop and enforce its own standards." The System's policy is its answer to the adjustment of big business to a democracy. Its deeds have borne out the genuineness of its words; and its efforts to follow a policy of public service have given rise to practices which constitute, in their application to the System, the "method" which Mr. Hoover sought.

News of the Month

F. B. JEWETT is named on a delegation of seventeen appointed by President Hoover to represent the United States at the World Engineering Congress meeting at Tokio on October 29. The congress will be held under the auspices of the Engineering Society of Japan and will discuss and exchange views on the latest knowledge of the science and practice of engineering. Mr. Jewett is scheduled to read a paper at the meeting. He attended a dinner given at the Carlton Hotel in Washington by the American Committee of the Congress in honor of His Excellency, Katsuje Debuchi, Japanese Ambassador to the United States.

While at Washington Mr. Jewett attended the annual meeting of the National Academy of Sciences. On the following day he was a guest at the White House luncheon at which the John Fritz Medal for 1929 was presented to President Hoover.

At the meeting of the Chicago Industrial Club in the Blackstone Hotel, Chicago, Mr. Jewett delivered an address on *What Industrial Research Has Done for Electrical Communication.*

On the occasion of the unveiling of the airplane *Bremen* on the Grand Central concourse, he was a guest of honor at a luncheon given by the Museums of the Peaceful Arts at Hotel Commodore. The luncheon was also attended by G. W. Elmen and P. Norton.

On June 7, Mr. Jewett gave the commencement address at California Institute of Technology, Pasadena, his subject being *The Scientist and Engineer as Citizens.*

Mr. Jewett has been made chairman of a committee appointed by the National Research Council to cooperate with the trustees of the Chicago World's Fair, which is to be held in 1933. The committee consists of representatives of the many fields of science in this country and will act as an advisory body in conjunction with the exhibitions of the achievements in science and invention during the last one hundred years, which are to be the dominant note of the Fair.

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MEMBERS of the Laboratories attending the Engineering Congress at Shawnee-on-Delaware included H. P. Charlesworth, R. L. Jones, H. D. Arnold, A. F. Dixon, H. H. Lowry, W. H. Matthies and B. W. Kendall.

RESEARCH

HERBERT E. IVES spoke at the one hundredth anniversary banquet of the Zelosophic Society of the University of Pennsylvania, of which he was president as an undergraduate. His subject was *Communication,* 1829 *and* 1929.

HARVEY FLETCHER, president-elect of the American Federation of Organizations for the Hard of Hearing, spoke over the N. B. C. chain on Thursday evening, June 20, on "Deafness." At the tenth annual convention of the Federation at Wade Park Manor, Cleveland, on June 24-27,

Dr. Fletcher was installed as president of the body.

KARL K. DARROW has left for California where he is giving a series of lectures at the summer session of Leland Stanford University on *Modern Physics* and *Advanced Theoretical Physics.* He expects to be absent from the Laboratories until the middle of September. He attended the meetings of the American Physical Society at Berkeley from June 19 to 23.

ON JUNE 3, C. J. Davisson spoke before a group of engineers of the American Telephone and Telegraph Company. His subject was *Wave Properties of Electrons.*

A. R. KEMP sailed on the "Aquitania" and J. J. Gilbert, V. E. Legg and J. F. Wentz sailed on the "Columbus" for Nordenham, Germany, where they will spend some time at the Norddeutsche Seekabelwerke, a subsidiary of Felten and Guilleaume of Cologne, in connection with the manufacturing development of submarine telephone cable.

C. H. G. GRAY sailed on the "Olympic" for London, Paris and Berlin, where he will discuss questions concerning the operation, application, and adjustment of the European Master Telephone Reference System.

D. G. BLATTNER left for Atlantic City on May 28 to attend the dedication of the recently erected Municipal Auditorium. The new auditorium contains one of the largest public-address and sound-picture equipment systems ever assembled.

DURING THE last week in May Mr. Blattner and H. F. Hopkins left for Orlando, Florida, to undertake tests with stethoscope transmitters in detecting the presence of Mediterranean Fruit Fly larvae in fruits. The tests were made in conjunction with Federal and State entomologists waging a campaign against the fruit fly larvae which are causing much damage to citrus fruits.

H. A. FREDERICK, with G. D. EDWARDS and A. F. GILSON of the Inspection Engineering Equipment, attended a conference of the Instrument Repair Committee at Hawthorne.

MEMBERS of the Research Department who attended the meeting of the American Chemical Society at Columbus included W. S. Bishop, C. L. Erickson, R. L. Taylor, R. M. Burns, H. H. Lowry, L. A. Wooten and L. H. Campbell.

R. M. BURNS, B. L. CLARKE, W. E. CAMPBELL, and H. E. HARING attended the meeting of the American Electrochemical Society at Toronto. A paper, *Electrical Resistance Method of Measuring Corrosion by Acid Vapors,* was presented by Messrs. Burns and Campbell.

L. H. CAMPBELL visited the Dupont Paint Laboratories in Philadelphia on May 9 and 10.

J. H. INGMANSON was in Texas in connection with the installation of tape armored cable.

P. A. LASSELLE was at the plant of the General Electric Company at Schenectady for the purpose of inspecting enamelled wire.

E. E. SCHUMACHER, J. H. WHITE and G. M. BOUTON made an inspection trip through the Bethlehem Steel Company.

J. A. BECKER presented a paper entitled *The Life History of Adsorbed Atoms and Ions* before the meeting of the American Electrochemical Society at Toronto.

A PAPER by H. A. Pidgeon and J. O. McNally, entitled *A Study of the Output Power Obtained from Vacuum Tubes of Different Types* was pre-

sented at the June meeting of the Institute of Radio Engineers.

Inspection Engineering

G. D. Edwards made visits to the Field Engineering Headquarters in Cleveland, Chicago and St. Louis during the latter part of May. Accompanied by G. Garbacz, Cleveland Field Engineer, Mr. Edwards also visited the Cincinnati and Suburban Telephone Company in Cincinnati in connection with inspection engineering work.

Mr. Edwards attended some of the meetings of the conference of operating company chief engineers held at Shawnee-on-Delaware.

During the first week in June, A. F. Gilson and S. H. Anderson were at the Elgin central office in Toronto in company with representatives from the General Electric Company to investigate and correct commutation difficulties experienced on an M-type generator.

W. E. Whitworth, Omaha Field Engineer, visited Fargo, Denver and Minneapolis in connection with field engineering activities.

R. M. Moody, H. C. Cunningham and C. J. Hendrickson were in Hawthorne, and Mr. Cunningham was also in Kearny to attend surveys of inspection and quality control methods for plugs, jacks, keys and relays.

R. C. Koernig visited Hawthorne to confer with the Manufacturing Department of the Western Electric Company regarding remedial measures in connection with engineering complaints.

Outside Plant Development

C. S. Gordon visited the Reliable Manufacturing Company of New Haven in connection with the production of strand dynamometers. While at New Haven Mr. Gordon also visited the Whitney-Blake Company in regard to drop-wire production.

C. H. Klein and B. A. Merrick were at New Haven during the latter part of May to witness field trials on span clamps.

S. C. Miller and A. W. Dring made a trip to Hawthorne to discuss matters concerned with the redesign of No. 14 Type Cable Terminals. Mr. Dring conferred with officials of the Bell Telephone Company of Pennsylvania in connection with the same work.

D. A. Quarles, J. B. Dixon, and E. M. Honan visited the Roebling Steel Wire Company of Roebling, New Jersey, on a trip sponsored by the New York Electrical Society. The visit was made for the purpose of inspecting the manufacture of suspension wire to be used on the new Hudson River bridge.

C. R. Moore made a trip to Washington to study methods of detecting leaks in cable held under gas pressure, in connection with work of the Long Lines Department. Mr. Moore was also at Philadelphia to study warning devices applicable to cable-leak detection. On May 20 he was at Mount Vernon, Tarrytown and Peekskill, carrying out investigations of methods of loading and blocking cable reels on freight cars.

D. A. Quarles, G. A. Anderegg, and C. D. Hocker made a trip to Texas during May, visiting chiefly the cities of Dallas and Fort Worth, to examine the condition of tape-armored cable buried in that region. Mr. Hocker extended his trip to San Antonio and Galveston to investigate motor-vehicle and metal finishes. He also stopped off at New Orleans to

supervise the burying, for experimental purposes, of cable-lead and iron samples covered with various protective coatings. On the return trip Mr. Anderegg spent a few days at Hawthorne to discuss general cable development matters.

SYSTEMS DEVELOPMENT

L. M. ALLEN spent several weeks in Denver in connection with circuit problems and the cutover of step-by-step equipment there. The cutover to the dial system was one of the largest in the country, involving the entire downtown section of Denver, which included about 40,000 offices. H. H. Lowry was in Denver as a guest of the Mountain States Telephone and Telegraph Company at the time the cutover was made.

F. S. ENTZ, A. E. BACHELET and B. A. FAIRWEATHER visited Allentown in connection with tests of program transmission over cable circuits. Mr. Fairweather also visited Morristown, Reading and Harrisburg in carrying on these studies.

D. M. TERRY, W. F. KANNENBERG and C. M. HEMMER were in Richmond during the past month to observe trials on 2-A automatic pilot-channel equipment.

D. E. TRUCKSESS was in East Pittsburg to discuss power problems with engineers of the Westinghouse Electric and Manufacturing Company, and in Fort Wayne to discuss similar problems with General Electric engineers.

J. A. KRECEK was in Chicago in connection with the installation of four-wire echo suppressors.

EVERETT HARRISON SMITH died on June 11 after an illness of three months. Born in 1887 in Leicester, Massachusetts, Mr. Smith attended Worcester Polytechnic Institute, and joined the Western Electric Company at Hawthorne in 1910. He was transferred to West Street for systems



E. H. Smith

engineering in 1919. Here Mr. Smith participated in the design of machine switching systems, and at the time of his death was in charge of the development of step-by-step dial equipment. The Laboratories deeply regrets the passing of so efficient a co-worker and so kindly a friend.

M. A. FROBERG visited Chicago and discussed various equipment problems with members of the staff at Hawthorne.

R. P. JUTSON visited Greensboro and Durham, North Carolina, where trials are being made on unit power supply equipment for repeater stations.

H. N. BOWMAN was in Hawthorne in connection with the manufacturing of a new design of testing equipment

which is replacing the present type of portable test boxes and test wagons.

H. E. MARTING was in Cincinnati to discuss building and floor-plan layouts with engineers of the Cincinnati and Suburban Telephone Company.

J. R. STONE and G. A. BENSON were in Des Moines in connection with the installation of centrifugal exhauster equipment for use with distributing systems for toll tickets.

H. M. SPICER was in Philadelphia to discuss the manufacture of power switches with General Electric Company engineers.

E. J. DONOHUE went to Syracuse to observe trials on out-trunk preselector equipment.

J. H. SOLE visited the General Electric Company plant at Schenectady to discuss alternator designs.

C. E. BOMAN and F. H. GRAHAM were in Hartford in connection with studies of step-by-step equipment.

C. E. BOMAN has been elected to membership in the Edward J. Hall Chapter of the Telephone Pioneers of America.

FERDINAND VOELKER, JR., of Toll Development, died May 12, 1929. Mr. Voelker had been with the Western Electric Company and the Laboratories since February, 1920, coming to us directly after his graduation from high school. He was an honor student in the Student Assistants' course and by virtue of his work in Equipment Drafting division was promoted into Equipment Engineering. Although only twenty-six years of age at the time of his death, Mr. Voelker had already established a high reputation in the performance of his duties with the Laboratories.

APPARATUS DEVELOPMENT

F. F. LUCAS visited the Watertown, Massachusetts, Arsenal to discuss metallurgical problems in connection with the manufacture of army ordinance with the Arsenal staff. On the twenty-first he was the guest of honor at a dinner at Henry Ford's Wayside Tavern, Sudbury, Massachusetts. On the twenty-second, Dr. Sauveur of Harvard and Mr. Lucas were the guests of honor at a dinner attended by members of the Harvard and M. I. T. faculties at the Harvard School of Business Administration.

C. E. NELSON spent the month of May and part of June in Harrisburg, Pennsylvania, in making noise measurements in the step-by-step office there. E. Montchyk also visited Harrisburg in this connection and D. W. Mathison conducted various experiments in reduction of noise at the same central office.

L. E. DICKINSON visited Hartford, during the month of May to measure contact resistances in the step-by-step office.

H. B. ARNOLD attended the National Electric Light Association convention at Atlantic City to explain the various technical aspects of power-line carrier equipment displayed in the Graybar exhibit at the convention.

J. E. CROWLEY spent several weeks at Atlantic City in connection with the installation of the public-address system in the convention hall.

O. L. WALTER visited Hawthorne to discuss changes in the manufacture of 202-B Reproducer Sets. Mr. Walter also spent several days at White Sulphur Springs handling the portable reproducer during the convention of general managers of Associated Companies.

R. V. TERRY spent several days in Rochester visiting the Bausch & Lomb Optical Company and the Eastman

Kodak Company in connection with reproducing lenses for sound pictures.

J. N. REYNOLDS and H. F. DOBBIN visited Hawthorne recently in connection with development work on dial apparatus.

W. T. PRITCHARD attended a conference at Harrisburg, Pennsylvania, with representatives of the American Telephone and Telegraph Company and the Bell Telephone Company of Pennsylvania on maintenance apparatus for the step-by-step dial system.

F. A. VOOS visited Hartford on May 31 to inspect the lubrication of master-switch governors.

G. W. FOLKNER and C. W. MCWILLIAMS were at Hawthorne in connection with new developments on multiple brushes and banks.

H. M. KNAPP and E. P. WILLIAMS were in Hawthorne during the week of June 3, to observe manufacturing methods.

B. F. RUNYON spent several weeks at Kingston, New York, on special studies of contacts in pilot-wire regulators for toll lines.

H. N. WAGAR was at Hawthorne for a month of engineering training.

J. E. SHAFER visited the radio station at Lawrenceville, New Jersey, in connection with development of overload relays.

J. R. FRY was at Hawthorne recently for a conference on magnetic materials for electro-magnetic apparatus.

W. L. BLACK and H. V. AKERBERG are supervising the installation of the speech input equipment for the new studios of the Columbia Broadcasting System in New York City.

A. B. BAILEY was in Gloucester to supervise the installation of the one-kilowatt broadcasting equipment for the Matheson Radio Company. He inspected similar equipment for the Outlet Company of Providence.

J. C. HERBER supervised the conversion to crystal control of the one-kilowatt broadcasting equipment of the Petroleum Telephone Company, Oil City, Pennsylvania. F. A. Hinners was in Akron performing a like service for the Allen Theatre.

O. W. TOWNER inspected the one-kilowatt broadcasting equipment of the Concordia Seminary, and the five-kilowatt broadcasting equipment of the Voice of St. Louis, both of St. Louis. During the past month he was at Raleigh to supervise the installation of the one-kilowatt broadcasting equipment of the Durham Life Insurance Company. Mr. Towner also supervised the installation and conversion to crystal control of the one-kilowatt broadcasting equipment of the Hotel Lassen, Wichita, Kansas.

PATENT

BETWEEN MAY 8 and JUNE 6, G. M. Campbell, E. V. Griggs, J. A. Hall, G. C. Lord, T. P. Neville, O. E. Rasmussen visited Washington in connection with the prosecution of patents. P. C. Smith was at Rochester during the past month on a similar mission.

GENERAL STAFF

ON MAY 14, S. P. Grace addressed the Los Angeles section of the American Institute of Electrical Engineers and a week later spoke before the combined meeting of the San Francisco sections of the American Institute of Electrical Engineers and Institute of Radio Engineers. While on his Pacific Coast tour, Mr. Grace also spoke before the Oregon Technical Society at Portland; the Engineering Society at Seattle; and the local sec-

tion of the American Institute of Electrical Engineers at Spokane.

W. C. F. FARNELL spoke before the General Conference Board of the Engineering Association of the Southern New England Telephone Company at Norfolk.

L. S. O'ROARK was a speaker at the annual convention of the Telephone Association of Vermont at Burlington; his subject was *Electrical Eyes.*

CONRAD SCHAUL, who has been with the Western Electric Company and the Laboratories for the past thirty-six years, employed as an instrument maker in the Development Shop, has been retired at his own request on May 20, 1929, and is now residing at 1033 Madison Street, Brooklyn.

JOHN LAWLESS, formerly of the Plant Department, died May 28, 1929. Mr. Lawless, whose service with the Western Electric Company and the Laboratories dated from November 12, 1901, was retired on pension June 13, 1928.

* * * *

A SERIES of night flights, from Hadley Field to Washington and return, was made by the Laboratories' plane from May 22 to May 25. These flights marked the first attempts on a comprehensive basis to undertake night experiments on radio telephonic communication between the plane in flight and the ground.

About two hours were required to make the trip each way. The flights were started shortly after dusk, landings were made at Bolling Field, Washington, and the return trips were started about midnight. Experimental trials were made at four different frequencies between 1500 and 6000 kilocycles. During most of the journey two way communication was maintained between the plane and the laboratory at Whippany. On three of the four frequencies, good telephone signals were had at Whippany as the plane soared high above the city of Washington. A model of the recently developed 50-watt No. 8-A Radio Transmitter was used in the plane during all of these tests.

Quite satisfactory flying conditions were encountered with the exception of the third flight on Friday, May 24, when, owing to frequent thunder showers, the return trip was made without landing at Bolling Field. On the first and third flights the plane was piloted by Capt. A. R. Brooks and the radio equipment was in charge of F. S. Bernhard. The plane was piloted by Thomas Durfee on the second and fourth flights, with E. F. Brooke in charge of the radio equipment.

The experiments undertaken during the past month, round out the plane's first year of service. In this period more than 260 flights have been made representing a total mileage in excess of 25,000 miles.

* * * *

A DEMONSTRATION of radio telephone transmission by the Laboratories' plane was given before the Board of Directors of the American Telephone and Telegraph Company on June 12, previous to the Board's regular meeting. The plane circled over lower New York within sight of the A. T. & T. building at 195 Broadway, permitting Directors to observe the plane as they talked over the radio telephone with Capt. A. R. Brooks who was at the controls. W. C. Tinus and W. E. Reichle of the Radio Development group of the Laboratories were in charge of the radio telephone

transmission apparatus in the plane.

Connection was made through the ground station at Whippany, over one of the regular trunk lines from Whippany to Jersey Toll, thence to the executive switchboard at 195 Broadway. Transmission from the plane to the ground was carried on at a frequency of 1608 kilocycles. Members of the Board of Directors who took part in the demonstration were: James S. Alexander, George F. Baker, George F. Baker, Jr., Charles P. Cooper, George P. Gardner, Walter S. Gifford, Henry S. Howe, and Owen J. Roberts.

Contributors to this Issue

W. WILSON, after receiving the B.Sc. degree from the Victoria University of Manchester, England, in 1907, pursued graduate work for three years there and for two years at the Cavendish Laboratory of Cambridge University. From 1912 to 1914 he was Lecturer in Physics at Toronto University—meanwhile receiving the D.Sc. degree from Manchester—then joined the vacuum tube research group of these Laboratories. He has been active in transatlantic and ship-to-shore telephonic development, and is now Assistant Director of Research in charge of groups concerned with radio and with vacuum tubes.

L. A. ELMER received the B.S. degree from the University of Minnesota in 1921, and the M.S. degree in mechanical engineering from Massachusetts Institute of Technology the following year. Coming directly to these Laboratories, he spent two years in the machine switching testing laboratory, and then joined the group engaged in developing the mechanical equipment for wax recording. He has been especially concerned with the design of vibration-absorbing drives.

Carrier current development has been the chief activity of Christian F. Boeck since he entered the Laboratories in 1919. In particular he was active in the initial installation of the Type B system, and in the development of picture transmission. He has been connected with power-line carrier since its early days and had charge of laboratory work on the single side-band system which he describes in this issue of the RECORD. Subsequently he took part in the installation of this equipment. While continuing his interest in power-line carrier, Mr. Boeck and his group have recently been concerned with public-address engineering, and with the installation of sound-picture equipment on trucks.

Mr. Boeck is an alumnus of Carroll College, Wisconsin, and had three years of graduate engineering studies at Wisconsin and Columbia.

F. H. HIBBARD attended Huron College and Cornell University, receiving the M.E. degree in 1914. After two years with the Western Electric Company, and a short time with the Maxwell Engineering Company and with United Theatre Equipment as Sales Engineer, he joined these Laboratories. From the dial apparatus testing laboratory, of which he was in charge after 1921, he moved for a short time into cost-reduction



Christian F. Boeck



W. Wilson



L. A. Elmer

work, then into the group developing electromagnetic apparatus, to supervise the design of step-by-step relays. Mr. Hibbard is now a member of Electrical Research Products, Inc.

When in 1919 Herbert E. Ives entered the Laboratories, he had already accomplished much in the field of optics, notably in color photography, in photometry, and in the production of "artificial daylight." Bringing to his new work an extensive knowledge of the photo-electric cell, Dr. Ives was placed in general charge of developments leading up to the telephotograph system, put into commercial operation in 1925. He was in charge as well of the development of the television system initially demonstrated in 1927. He directs a group which investigates not only the general problems of picture transmission and television, but such specific details as the photo-electric cell and the glow-discharge lamp.

Sixty per cent of the world's telephones are in use in the United States, according to recently published world telephone statistics. These statistics, compiled up to January 1, 1928, *show that the total number of telephones in the world on that date amounted to* 30,990,304, *and the actual number possessed by this country was* 18,522,767. *Europe had* 8,623,407 *telephones, or about* 28 *per cent of the world's total, and the remaining* 12 *per cent were distributed widely throughout the rest of the world. The year of* 1927 *showed an increase of* 1,583,743 *in the total number of telephones in use, one-half of which representing those added in the United States.*

Notes of the Club

THIRTY brightly colored bathing caps flashed and dipped, porpoise-like, in cool green waters while watchful judges and envious spectators looked on from the vantage point of a nearby golf course. The occasion was a water sports competition for Club mermaids on the initial women's night at the Indoor Athletic Club, June 5. The scene resembled the Hollywood idea of a pool party on a Long Island estate, what with the golf green, gay colored chairs and bathing girls.



After warming-up exercises on the vibrators and handball courts, the girls were ready for the water races under the expert direction of Miss Wyckoff of the Kittredge School and Miss Spranger of the Carroll Club. Miss Spranger had the pleasure of seeing some brilliant performances by her erstwhile pupils in the swimming classes. The lone aerial event on the program was the balloon race. Only a few girls succeeded in pushing a toy balloon the length of the pool but, owing to the difficulty in keeping a straight course, all had admirable success in pushing each other the width of the pool. Less spectacular but more picturesque was the affair called the Statue of Liberty or candle race. Several maidens gracefully glided down the pool each bearing aloft a lighted candle. One elected the submarine style but was beaten out by the faster sub-chasers.

In the sixty-foot splash and dash finals, Patience Penney nosed out Marianne Grimm for first place. In the walking race, Mary Reddington walked away from Valerie Beers and the remaining entrants to win first place, Miss Beers finishing second. In the Dead Man's Float, Mabel Wood and Margaret Tully floated longer, farther and better than the others, taking first and second place.

A novelty was the Chip Picking contest in which Marie O'Neil showed an uncanny eye for poker chips by finding seventeen at the bottom of the pool. Miss Jackson was next with fourteen chips.

The candle race finished as follows: Louise Fitzgerald first, Virginia Rathgeber second. Patience Penney won first as the best balloon pusher and Florence McCann was next best.

Medals were awarded to the winners of first places and pins to those of second places.

The dive-and-sprint racers were not only fast, but impartial in their splashing. L. P. Bartheld, who acted as master of ceremonies, timekeeper and candle lighter, had a natty gray suit

put badly out of press by reckless splashers. Marie Boman and Leona Feil also had the misfortune to be splashed. In fact, a good splashing was enjoyed by all.

The swimmers and spectators were then treated to an exhibition of various styles of swimming and life-saving by the Misses Spranger and Wyckoff which was received with generous applause. The meet then broke up into free-for-all swimming and diving, golf, handball, the showers, and the free-for-all subway ride home.



E. C. Mueller sinks a long putt

Fore!

Traps to the right of them and bunkers to the left of them, into the wind drove the 81—and so started the golf tournament at the Salisbury Country Club.

The day, Saturday, June 1, was perfect for golf and from the number of scores under 90 our Hagens, Farrells and Diegels forgot what might happen to their handicaps and shot some near-par golf. In Class "A," Kellogg turned in the lowest score for all B. L. C. tournaments, a gross 79, and won the low-gross prize for qualifying round. Clark, Hillier, Cesareo, Achenbach and Wood were right behind him with scores in the eighties. Class "B" had nine men breaking 100 and the honors in this class were shared by E. Peterson and T. P. Ingram. Korn led Class "C" with a gross 101, net 67, followed closely by Greenidge who had a gross 103 and a net 68. Achenbach and Ingram were tied for the low net prize in the qualifying round, but Ingram's net 63 in the finals was low enough to defeat Achenbach.



Fairlamb grazes the edge of the cup

The finals were held Saturday, June 8, and reminded one of those cold windy days we hear so much about on the golf courses of Scotland. The first three foursomes teed off in the rain but the gods were good—the rain stopped and the wind died out, leaving our men a perfect golf day and incidentally lots of work for the handicap committee.

The prizes were awarded on the basis of total gross and net scores for 36 holes. Low-gross prizes were wrist watches and were won by Kel-





Above, Bart explodes one out of the sand; left, "Jonny spielt auf"; below, Leon Hoyt gives Andy Lawrence a lesson on how to chip up







Above, Chairman Kennelty raises a smoke screen; right, believe it or not, Kellogg turned in a gross 79; below, Achenbach drives out a long one



logg, Class "A," with a total 165 for 36 holes; in Class "B" by Hoyt with a 185; and by Korn in Class "C" with 201. Trophies were awarded for the low net scores in each class and were won by Achenbach, Ingram and Crawford. Wallets for the second low net scores were won by Downing, Lacerte and Bittner in their respective classes. Golf balls for third low net were won by Clarkson in Class "B" and Greenidge in Class "C."

The fall tournament will be held at the Salisbury Country Club on Saturdays, September 21 and 28.

Beach Combing at Brighton

Retaining its ancient glamour of the horse and carriage era as a select bathing resort, Brighton Beach in modern dress continues to attract the seekers after salt air and sea bathing. Rapid transit facilities and the longer day make it possible to dip in the brine after a hot day's work and loaf back to town in a 40-an-hour bus. And then the Club arrangement for special half-price tickets goes for Saturdays and Sundays also, enabling bathers to avoid the usual long lines. The Club feels it is fortunate in having secured these special privileges for its members, and if tickets sold is a criterion the Club members likewise endorse the idea. Tickets on week-days are only fifty cents and on Sundays and holidays one dollar. Club membership cards must be shown with tickets which are available from the Club secretary, Room 164.

Carroll Club Swimming Classes

Swimming classes are again being held during the summer season at the Carroll Club. This gives an opportunity to those who have benefited so much in the past by the swimming classes to continue their progress under the Misses Spranger and Wyckoff. New swimmers who are interested are also welcome and should get in touch with Katherine Tully.



BELL LABORATORIES RECORD

TRANSATLANTIC SHORT-WAVE RADIO

Technically Described by

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M. E. FULTZ
E. B. FERRELL
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The Story of Short-Wave Transoceanic Telephony

By A. A. OSWALD
Research Department

THE year 1924 brought forth the conclusion that the results of two years of previous work on short waves justified an active interest in the problems of short wave operation on a large scale. Orders to build at Lawrenceville, New Jersey, came in 1928; 1929 sees the station in operation. The development and installation of the United States terminals for the four new transoceanic radio-telephone channels is a splendid example of cooperation in research and engineering. Extending over a half-decade, the project which culminates in the stations at Lawrenceville and Netcong, New Jersey, and their counterparts in England involved the work of several score of engineers, scientists and others. By tracing the history of the work, there may be given a new impression of its magnitude; by mentioning some of the men who contributed, an idea may be conveyed of the variety of talents required for its success.

Until the latest stages of this work brought its problems of systems development, short-wave investigation was confined to groups working at first under H. W. Nichols and after his death under W. Wilson. Late in 1921 R. A. Heising and J. F. Farrington began a study of methods of generating and receiving radio signals with high frequencies and measuring the intensities of their fields. These investigations dealt with comparatively low powers, not exceeding about 200 watts; so successful were they that the design of higher-powered equipment was initiated. J. C. Schelleng and E. B. Ferrell, working on short-wave transmitters, developed power amplifiers, for association with Mr. Heising's high-frequency oscillators, to the point of putting from three to five kilowatts into the transmitting antennas. J. C. Gabriel and G. Thurston, under the direction of Mr. Farrington, further developed the generating and modulating circuits and added crystal control. With the added power field-strength measurements



Engineers in charge of the development of the short-wave radio transmitters and receivers. Left to right: A. A. Oswald, M. J. Kelly, W. Wilson, R. A. Heising, J. C. Schelleng, H. T. Friis

were made on several wavelengths at distances up to a thousand miles in various directions. Meanwhile H.T. Friis and E. Bruce concerned themselves with short-wave reception, and devised suitable antenna systems, receivers, and field-strength measuring equipment.

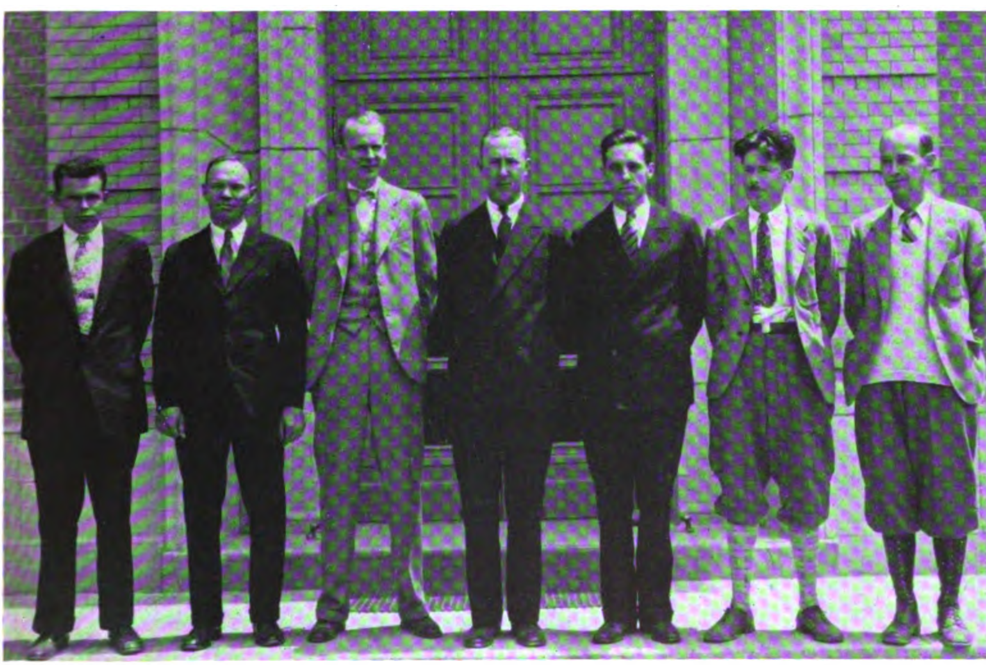
A further simultaneous survey of field strengths at great distances over a wide area was then made; using the various portable measuring sets that had been developed, men from the Laboratories and the American Telephone and Telegraph Company made observations on signals from Deal at numerous distant posts. Participants in this experiment were: C. R. Englund, F. B. Llewellyn, and F. H. Willis (A.T.&T.), first at Cleveland and later at Chicago; J. G. Chaffee, E. J. Sterba, and S. Wright, first at Minneapolis and later at Dickinson, North Dakota; J. F. Farrington, E. G. Ports, and E. A. Krauth, first at Shelby, Montana, and later at Seattle; C. V. Litton, H. C. Baumann, and G. M. Eberhardt, on a truck moving from fifty to three-hundred miles west of New York; F. R. Lack, G. Thurston, and G. Southworth (A.T.&T.), on the steamship "Republic" bound for Bremen; E. Bruce, F. A. Hubbard, and G. D. Gillett (A.T.&T.), on the steamship "Minnewaska" bound for London; and A. G. Jensen, at New Southgate, England. Between Deal and New Southgate, where Mr. Jensen has been assisted by English engineers, these observations have continued up to the present.

The good results of the tests warranted a commercial trial; in 1927 the Deal transmitter was associated with the New Southgate receiver as an eastbound short-wave experimental channel, auxiliary to the long-wave system which was by that time in full commercial operation. During that summer it could always be used in

combination with the long-wave westbound channel, and, indeed, it was in use more than half the time, under the direction of N. F. Schlaack. This operation clearly demonstrated the complementary properties of long-wave and short-wave systems. Of the two major hazards to good radio transmission, static and magnetic "storms", the long-wave system proved adversely affected by the former and comparatively little affected by the latter, whereas the short-wave system showed the reverse properties.

So ended the initial experimental stage of the development, the stage in which the fundamental circuits were determined. The design of a first commercial transmitter was next undertaken by the late H. R. Knettles, under the supervision of the writer and assisted in the mechanical design by J. L. Mathison. E. J. Sterba and E. B. Ferrell worked at Deal on directive transmitting antennas; Messrs. Friis, Bruce and R. S. Ohl continued at Cliffwood their work on directive receiving antennas and other receiving problems. The first transmitter designed with commercial operation in view was installed at Deal, and at Cliffwood a receiver was built by H. C. Baumann to serve as a model for later commercial design.

The success of the short-wave development and the increase in transatlantic traffic over the long-wave system combined to decide the American Telephone and Telegraph Company and the British Post Office to establish a complete two-way short-wave channel, to be opened June 1, 1928. To a site purchased at Netcong the Cliffwood receiver was accordingly



Engineers associated with the development of the radio transmitters, on the steps of the main building at Lawrenceville. Left to right: E. B. Ferrell, F. F. Merriam, A. Oxehufwud, N. F. Schlaack, C. F. P. Rose, N. E. Sowers, E. J. Sterba



Engineers associated with the development of the radio receivers. Left to right: F. A. Hubbard, F. A. Polkinghorn, J. C. Gabriel, J. L. Mathison

moved by E. J. Howard and L. R. Lowry, for use in association with the transmitter at deal. Systems groups,* which had designed wire-line equipment for the long-wave channel, installed at Deal, Netcong, and Walker Street the necessary additional equipment, incorporating improvements made in the meantime, and the channel went into service at the time scheduled.

But use of the transatlantic service was increasing so rapidly that the American Telephone and Telegraph Company found that more channels and facilities independent of those at Deal would be necessary to handle the business. Ordering in May, 1928, a channel to replace Deal, and two more to England and one to South America, the American Company purchased in August a transmitting site at Lawrenceville and scheduled the opening of the first transmitter for June 1, 1929. The intensive work necessary to meet this date was immediately started by these Laboratories and the Long Lines Department. Mr. Schelleng continued circuit studies toward further improvement of the transmitters, and Mr. Friis of the receivers; the coordination of the group activities of the Laboratories, and the design and layout of the apparatus and stations, were the responsibility of the writer.

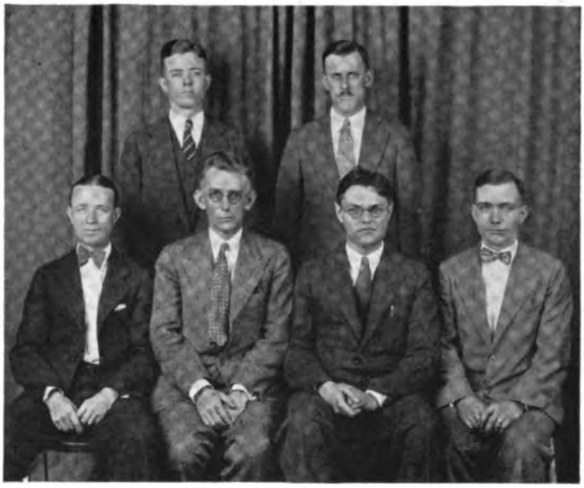
M. E. Fultz, C. F. P. Rose and A. Oxehufwud, assisted by J. L. Mathison, redesigned the transmitter in accordance with experience gained at Deal and incorporated crystal-oscillator systems based on the work of F. R. Lack. N. F. Schlaack and E. B.



The Laboratories' short-wave receiving laboratory at New Southgate, England, where A. G. Jensen (right) is assisted by R. Hamilton and other British engineers

* Bell Laboratories Record, *April, 1926, page 44.*

Ferrell set up and tried out at Deal all doubtful features of the new design. M. E. Fultz and F. F. Merriam, in cooperation with the American Company's architects, prepared the station plans, including the safety system and other operating features. In September the Long Lines Department broke ground at Lawrenceville, and by January the station was sufficiently advanced to permit installation of the power equipment. Technical supervision of its installation and test was given by Messrs. Oxehufwud and Rose, assisted by B. H. Nordstrom, and by T. J. Crowe, experienced as foreman of the Plant Department's electricians. Messrs. Ferrell and Rose, and N. E. Sowers, conducted tests and adjustments on the radio apparatus. Messrs. Sterba and Merriam, assisted by G. M. Eberhardt and P. H. Smith, designed the antennas and transmission lines and gave technical supervision to the Long Lines crews which erected and tested them. Work extended to holidays and artificially illuminated nights. Tracings taken in late evening from drafting boards under Mr. Mathison's supervision at West Street were rushed to Lawrenceville to guide the following morning's work.



Engineers associated with the development of the wire-line terminal equipment. Left to right: front, W. F. Malone, C. C. Munro, F. L. Morgan, H. M. Pruden; back, P. V. Koos, H. H. Spencer

Meanwhile F. A. Polkinghorn, with the assistance of F. A. Hubbard, J. C. Gabriel, E. G. Ports, J. L. Mathison and H. L. Holley, supervised the design and construction of a receiver based on a model constructed and tested in the Laboratories. This model incorporated many new features of commercial form but embodied substantially the fundamental circuits previously determined by Mr. Friis and



Engineers in charge of the development of the wire-line terminal equipment. Left to right: front, D. C. Meyer, E. J. Johnson, R. H. Kreider, E. Vroom; back, K. M. Fetzer, J. E. Cassidy, E. D. Johnson, J. L. Larew

his group at Cliffwood. The set, wired at West Street by A. C. Chaiclin and tested there by Messrs. Gabriel and Hubbard with the assistance of A. Hartmann and D. M. Black, was finally installed at Netcong by Messrs. Hubbard and Black, who then gave it further tests with the cooperation of the Department of Development and Research. Mr. Bruce, assisted by L. R. Lowry, R. M. Whitmer and F. Giovanini, gave technical supervision to the erection of the receiving antennas by Long Lines crews; tested the antennas; and substituted, for the open-wire transmission lines previously used, the concentric-pipe transmission lines developed by C. B. H. Feldman at Cliffwood.

At transmitting, receiving, and control stations, the work of the Systems Development Department on voice-frequency equipment was meanwhile being completed. E. D. Johnson, of R. S. Wilbur's group, prepared the circuits for line-terminal audio-operation and testing, with the assistance of E. Vroom, C. C. Munro, and H. M. Pruden; and J. A. Coy, working under D. C. Meyer, made general layouts of the necessary equipment. Detailed engineering of equipment, and its installation, was then undertaken by E. J. Johnson's group. Under J. L. Larew the wire-terminal power plant for Lawrenceville was designed and tested by H. H. Spencer, and for Netcong and Walker Street by R. P. Jutson. All other telephone equipment became the concern of R. H. Kreider, under whom J. E. Cassidy and P. V. Koos designed and installed equipment at Lawrenceville, W. H. Bendernagel and F. L. Morgan at Netcong, and R. B. Simon, W. F. Malone, J. D. Nedelka, F. A. MacMaster, J. N. Loomis and E. A. Bescherer at Walker Street. This work was complete when E. D. Johnson's group returned to test its circuits in their actual physical embodiment and announced them satisfactory.



Engineers associated with the development of short-wave vacuum tubes. Left to right: front, H. A. Pidgeon, V. L. Ronci; back, H. E. Mendenhall, J. O. McNally

Contributions from other groups were too numerous for complete mention. Of special interest are a band-pass filter, to operate at an intermediate radio frequency of about four hundred kilocycles, from C. E. Lane and his men; and a new differential relay from J. R. Fry's group. In the vacuum-tube laboratory directed by M. J. Kelly, special tubes for receiving circuits, including new shield-grid types, were developed by H. A. Pidgeon and J. O. McNally, and new power tubes for the transmitters were developed to meet high-frequency requirements by H. E. Mendenhall, V. L. Ronci and C. E. Fay.

Throughout all the development, moreover, the unfailing support, extending to overtime work, of the Plant and Commercial Departments



J. A. Coy



F. R. Lack



E. Bruce

was indispensible. In a special shop in 4-K, F. Berger took charge of building the transmitting and receiving sets. By arrangement with B. B. Webb's group, maximum assistance in the commercial phases of the work was secured. W. F. Johnson, assisted by H. W. Dippel and R. W. Mutchler, arranged for the purchase and delivery of the necessary materials from suppliers. Under K. B. Doherty, J. F. Lewis handled estimates, case-authorization, ordering and billing; and G. F. Doppel the manifold problems of scheduling and production, with the assistance of C. W. Stevens and H. S. Enger at West Street and P. May at Lawrenceville. C. Deyo took charge of storage, and of export to South America.

On June 1 as scheduled a year before, the first transmitter at Lawrenceville was cut into operation, and commercial service was initiated by a call from Cleveland to London. A week later the new channel was reported by the Long Lines Department as giving substantially better service than either of its predecessors. The second channel, replacing Deal, will be opened on September 1, and the third on December 1. Service to South America, where E. J. Howard is now making transmission observations on signals from Deal, opens next February.



Fairchild Aerial Surveys, Inc.

General view of the grounds at Lawrenceville

Transmitting Station at Lawrenceville, N. J.

By M. E. FULTZ
Research Department

AT the request of the American Telephone and Telegraph Company, the problem of planning a four-channel short-wave radio transmitting station, for commercial telephone service to Europe and South America, was undertaken in the spring of 1928. The selection of transmitting frequencies, circuits and antennas to be used, was based upon experience with the installation at Deal and the development work conducted at that station during the previous two years.

Due to the particular type of antenna selected, and the fact that each transmitter was to operate on any one of three assigned frequencies, a total of twelve independent antennas for the four channels was necessary, each requiring a linear distance of 500 feet for its structure. These antennas have directional characteristics which necessitate placing them broadside to the direction in which transmission is desired. Since it was not considered advisable to place obstructions directly in front of any antenna, straight line formations were selected. With this arrangement, an extremely long line of towers results when several channels transmit in the same direction. This is the case at Lawrencevile, N. J., where three of the four transmitters work to England.

The space requirements for a single antenna were arrived at on the basis of a fixed linear distance between towers which would most satisfactorily accommodate any one of the three antennas. This was done so that all tower spacings would be uniform and flexibility obtained for shifting groups or interchanging the antennas in a group in case it was later found desirable to make such changes.

In order to avoid undue loss in the transmission lines feeding these antennas, each transmitter should be located as nearly central to its three antennas as possible. It was, therefore, decided to separate the four transmitters and install not more than two in a single building. Accordingly two two-story buildings identical in layout, insofar as the transmitter installations are concerned, were erected by the American Telephone and Telegraph Company.

On the ground floor of each building, occupying the entire width at the rear, are transformer vaults and rooms for water-cooling units. Directly in front of these and also extending the full width of the building is the power room, a general view of which is shown in Figure 1. There are three motor-generator sets to a group for supplying power to the various units of one transmitter, and three such groups located in this room. The left and right hand groups are the regular machines for the two transmitters, while those of the middle group serve as spares for either. Between each group of machines, in a

screened enclosure, is located a transfer switch unit. It consists of three groups of double-throw gang-operated switches, which, when thrown in the proper direction, substitute entire spare motor-generator sets, including their automatic starting compensators, for the corresponding regular units associated with a transmitter. An interlocking system prevents the simultaneous use of a spare motor-generator set on two channels.

On the right hand side of the room is a standard twenty-four-volt power plant to meet the requirements of the telephone line-terminal equipment. On the left, between the first two automatic starting compensators, one of the generator noise filters is visible. This particular filter, the coil of which has a current-carrying capacity of six hundred amperes, is used in the supply line to the filaments of the transmitter tubes. Water pumps, water storage tanks, and a motor-generator set for sleet-melting, are also located in the power room.

As a precaution against vibration in the building, all rotating machinery was mounted on concrete piers which rest on cork mats several feet below the power room floor. Cork linings surround these piers where they pass through the floor.

Directly over the power room and of equal floor area is the transmitter room (Figure 2). Here are located two transmitters, in line, on one side of the room and two power-control boards, in line, on the other. A transmitter and its power-control board face each other with a seven foot aisle between them. Associated with each transmitter is an audio-frequency control turret, located on a desk which stands in this aisle near the center of the room. The radio operator, in this position, can communicate directly

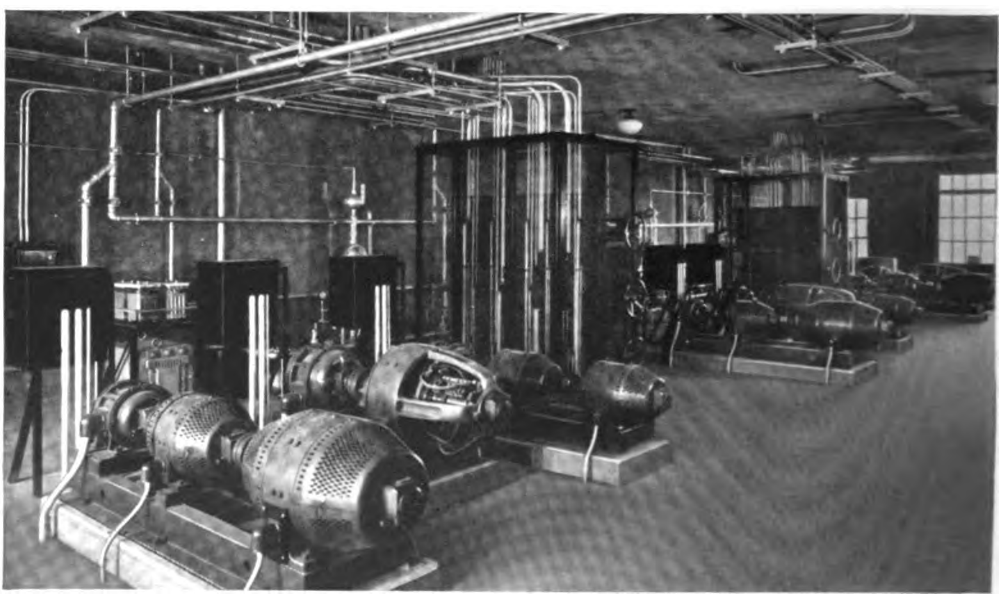


Fig. 1—General view of power room, showing the three groups of motor-generators (the center one a spare) for supplying the power to the transmitters, and the two screened transfer switch units

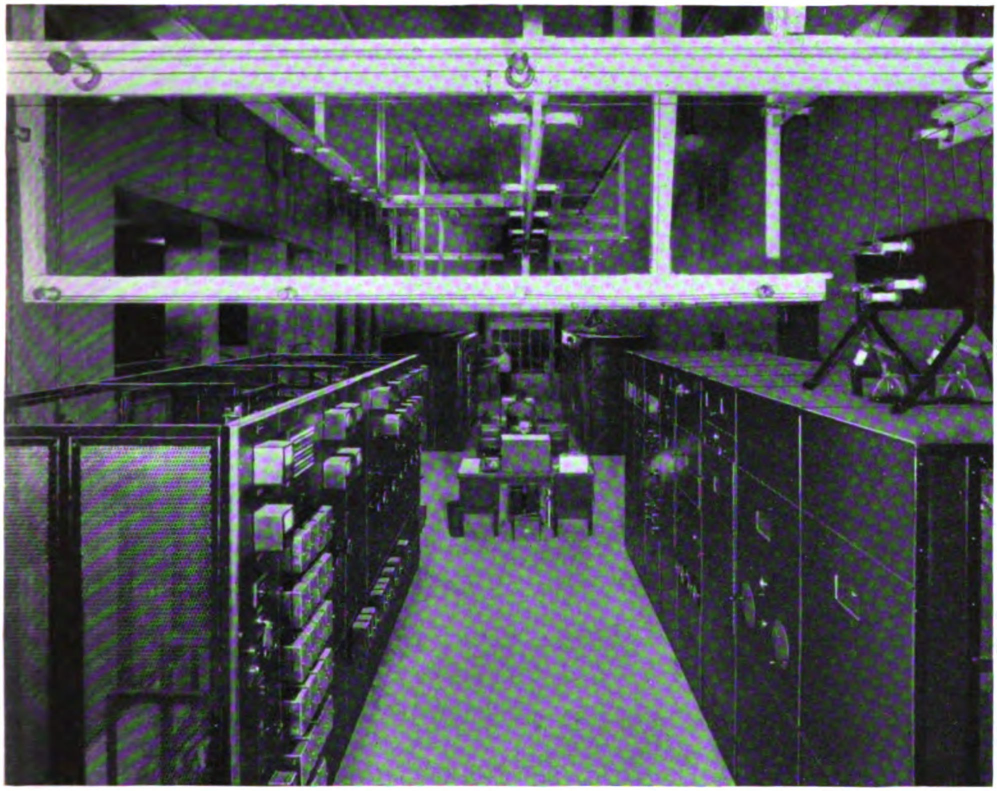


Fig. 2—General view of transmitting room. Left, power boards; right, transmitters; center, monitoring desks; left center room, rectifiers

with the New York control operator and monitor the input and output of the radio transmitter.

Extending back over the top of the middle transformer vault from the center of the room, and at a slightly higher floor level, is a room containing two six-phase high-voltage rectifiers (Figure 3), for supplying direct current to their respective transmitters. Beneath the rectifiers, on each side of the middle transformer vault, is a high-voltage switch chamber. Each contains a double-throw 25,000-volt switch by means of which either rectifier can be transferred from its regular transformer to a common spare. The transfer not only involves substituting a transformer but also all other equipment located in a transformer vault. In addition, therefore, to the eight high-voltage connections, provision is made for changing control circuits and the connections to certain protective features by mechanically connecting a twelve-pole double-throw switch to the high-voltage switch. With this arrangement a complete substitution of transformer-vault equipment is possible by operating a single switch handle in the transmitter room (Figure 4).

The equipment comprising each transmitter proper is contained in seven independently shielded units mounted side by side on a common sub-base. Three of the units are devoted to input equipment and the

other four to power amplifiers and their associated circuits.

The power-control board (Figure 5) consists of motor-generator control-panels and distribution panels, nine in all, equipped with the necessary apparatus for controlling and applying power to the associated transmitter. All apparatus is remotely controlled from this point. Independent control of the various motor-generator sets may be had from their respective panels and power applied to the transmitter by working in the proper sequence. The final step is the application of high voltage to the plates of the power-amplifier tubes, which is possible only when conditions are such that it will cause no damage. The fulfillment of these conditions is insured through the agency of an alarm and protective circuit, which is also effective in turning off the high voltage should trouble develop while the transmitter is in operation. It consists of a group of relays with associated signal lamps and may justly be termed the guardian of the transmitter. Most of these relays are located on the second panel from the left and are clearly visible in Figure 5. The signal lamps, of which there are forty-eight, are located within the rectangular area at the top of the panel. Thirty-six of these lamps serve to indicate circuit conditions prior to applying high voltage to the transmitter and causes of interruptions thereafter. These indications are specific to the more probable difficulties, and group the remaining in such a manner that their causes may readily be determined.

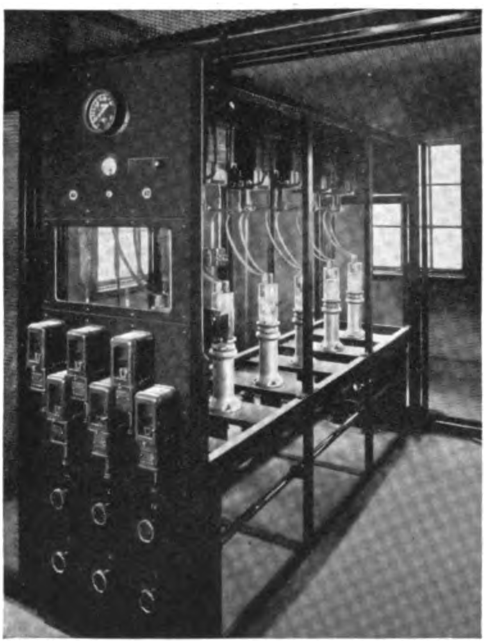


Fig. 3—One of the two six-phase high-voltage rectifiers for supplying direct current to the transmitters, located in a raised room leading off the center of the transmitting room

A guardian is not always infallible; sometimes it becomes necessary to guard the guardian. To this end the power supply for the alarm and protective circuit has been subdivided into twelve independently fused circuits. Twelve signal lamps connected to the load side of the fuses indicate fuse and power-supply conditions on these circuits. The lamps have a two-fold purpose: they indicate whether the alarm and protective circuit is telling the truth; and if it is not, they reduce to one-twelfth the places where this circuit is to be investigated for trouble.

When trouble develops in the transmitter itself, the protective circuit disconnects the high-voltage plate supply to the power amplifiers. Some of the conditions which cause this circuit to function are: overloads in amplifier and rectifier anode circuits; excessive water temperature; and failure of grid-biasing potential, filament-heat-

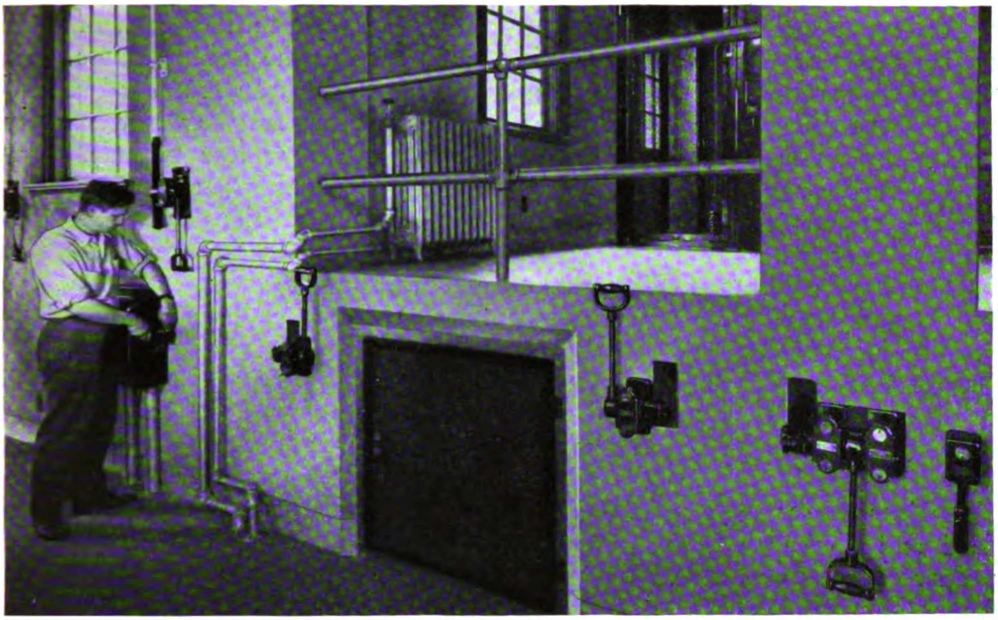


Fig. 4—Switch-handles of the interlocking system, in the transmitting room

ing supply or water flow. Each time an interruption occurs, one or more lamps go out and an audible signal operates for ten seconds to attract the station-operator's attention. By consulting the signal-lamp panel, causes for interruptions, and in most cases the particular thing responsible, may readily be ascertained and the transmitter returned to service with a minimum loss of time. An effective system should always indicate danger when something happens, regardless of whether it is a bonafide failure in equipment or a defect in the signal itself. In the system used at Lawrenceville, signal lamps operate on the principle of "light on" when conditions are correct and "light off" when trouble occurs. Had the reverse scheme been selected, a burned-out lamp might cause endless delay. A dark lamp in the present system, when the circuit is operating normally, convicts itself.

The power-control board has also been equipped with a master control system, to facilitate operations during routine handling of the set in commercial service. By throwing one switch the master control may be cut into or out of service. If it is in service, all equipment is automatically started and power applied to the transmitter by momentarily depressing the master "start" button. This completes all necessary operations up to the final step of applying the high voltage to the power amplifiers. The transmitter may be shut down by depressing the master "stop" button.

Each channel is provided with its own water-circulating system for cooling the anodes of the rectifier and power-amplifier tubes. It is, while operating, a closed circulating system, consisting of two water pumps, a water meter, three water-cooling units (Figure 6), a storage tank, and the necessary valves and the like. A closed circulating system is one in which the column of water is unbroken from

the discharge side of the pump to the suction side. At Lawrenceville this is the condition which exists when the pump is operating; but, as soon as the pump stops, all water drains from the cooling units, and the pipes to and from them, into the storage tank in the power room.

In designing a water-cooling system for vacuum tubes it is important to prevent aeration of water and to eliminate air circulating in the water columns around tube anodes. Precaution against trouble from the latter was taken by the installation of air valves at strategic points in the feed and discharge lines. For the proper operation of the cooling units it is necessary to locate them in a room open to the outside atmosphere and for this reason draining is essential to prevent freezing of the water in winter during idle periods. Although the discharge side of the system drains when the pump stops, water is retained in the tube jackets at all times by check valves in the feed line. Only one of the two pumps is used to circulate water. Either can be cut into service, and a change from one to the other can be effected, from the power control board. It is unnecessary to operate valves, and the attendant, therefore, is not required to leave the transmitter room in order to make a change.

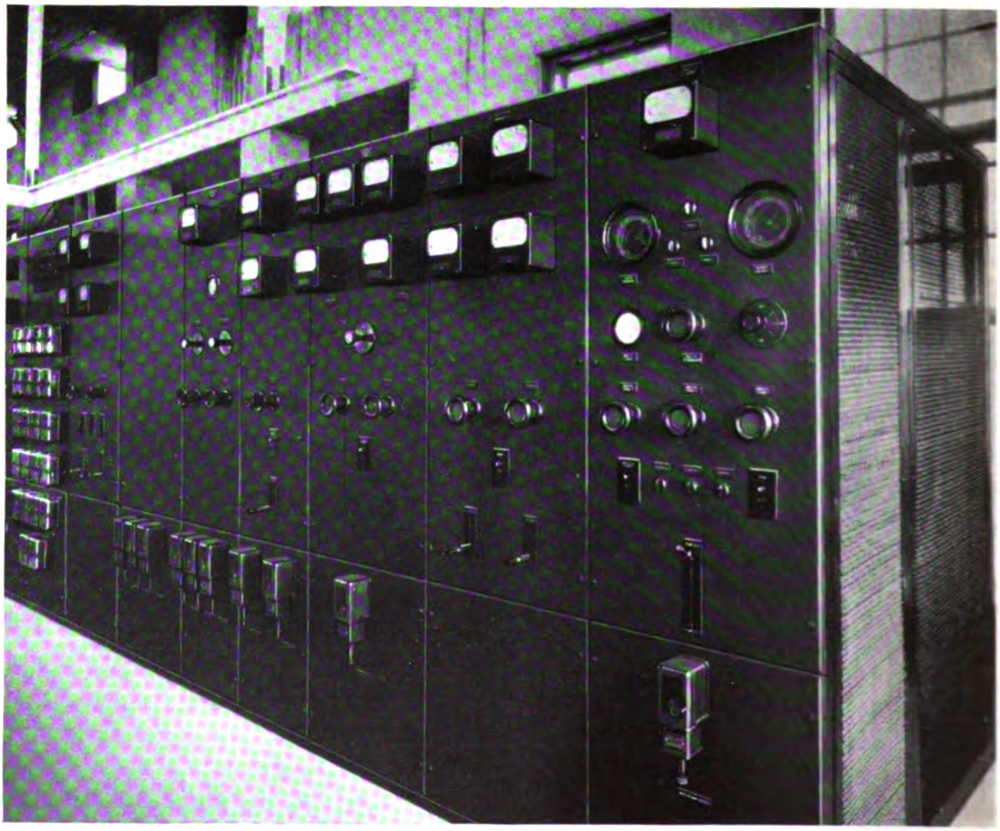


Fig. 5—One of the two power-control boards, in the transmitting room, for remotely controlling the power supply to the transmitters



Fig. 6—The three water-cooling units associated with water-cooled vacuum tubes in transmitters and rectifiers

At present one and eventually two three-phase power-transmission lines, following different routes from the Lawrenceville substation of the Public Service Electric and Gas Company, will supply power to the radio station. At the property edge the overhead line terminates and underground cable-runs continue to outdoor substations. Each building has its own substation, where the voltage is stepped down from 4000 to 2300 volts, and whence four 2300-volt cables supply all power for the building.

Two of these cables, each of which supplies one transmitter, terminate in the power-transformer vaults of their respective transmitters. A bank of step-down transformers in each vault supplies all auxiliary power requirements for one transmitter at 220 volts. The main load, the rectifier transformer, connects directly to the 2300-volt supply and steps up the voltage to 12,600 maximum. A tie cable between the two power-transformer vaults permits the operation of two transmitters on a single cable in case of a failure on one cable.

The other two 2300-volt cables, one of which is a spare, provide for the building's light and power requirements. They terminate in a vault in another section of the building which is altogether independent of the transmitter layouts.

For the safety of personnel and the protection of equipment in the

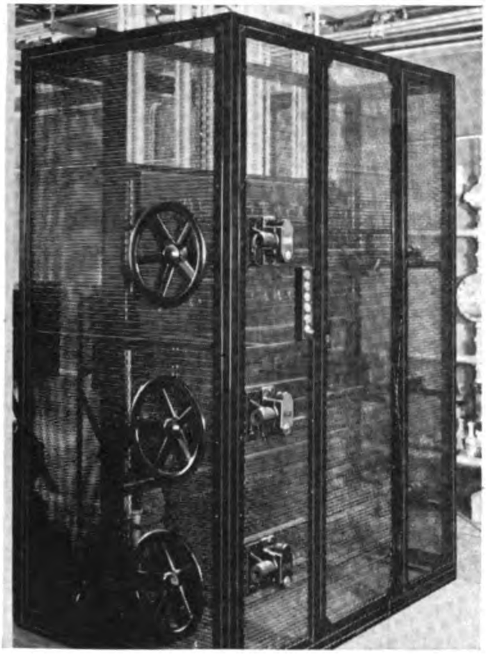


Fig. 7—One of the two transfer switch units, in the power room, for substituting motor-generator sets

plant an interlocking system has been adopted which is similar to that employed in modern central power stations but modified to meet the special requirements of the radio installation. It is a mechanical, key-operated scheme, in which the locking units are attached directly to switch-operating handles or vault-enclosure doors. Its protective feature lies in the fact that

a particular key is required to perform a certain operation. The completion of the operation locks the key in the unit and releases another key which permits executing a subsequent operation. In some cases where several conditions must be satisfied before it is safe to replace a key, a unit known as a transfer-key interlock is used, in which several keys are required, each in its proper place, to free a single key.

Some operations which the interlocking system prevents are: opening disconnect switches under load; gaining admittance to "live" enclosures; throwing switches in the wrong sequence; and tying two transmitters to a single spare piece of equipment. The layout is arranged for operating convenience, and in such a manner that its use will not occasion undue loss of time. To this end, for example, the disconnect-switches in the transformer vaults are remotely controlled by operating handles located in the transmitter room (Figure 4).

A near view of one of the transfer-switch units appears in Figure 7. Here the interlock units controlling the movement of the switches, a key box, and an enclosure-gate lock, are clearly visible. The key permitting entrance to this unit occupies the lower position of the key box. It is shown in place and not available until five conditions have been satisfied, and five keys obtained and inserted in their proper places in this unit. Upon removing the lower key the other five are locked in place and not obtainable until the removed key has been returned. The key operating any enclosure gate is not recoverable until the gate has been closed and locked.

This safety interlocking scheme is not confined to equipment within the building. It is a progressive system extending from the main 4000-volt power supply disconnect-switches, through the substations and buildings, to and including the antenna disconnect-switches.

The transmitters proper are not equipped with interlocking units such as have been described. Protection is obtained by an electrical system employing electric door-locks and door-switches, entirely automatic in its operation. Except by force or other unusual methods, access to any compartment is not possible until the high-voltage supply line to the transmitter has been grounded. In performing this operation, all sources of power supply to the transmitter, except that for heating filaments, are disconnected, and then all door-locks are energized. Upon opening any door, the grounding switch is locked in the grounded position and is not released until all transmitter doors have been closed again.

Adequate provision has been made for the expansion of this multi-channel transatlantic project. The present property will accommodate several more two-channel buildings of the present type, and their necessary antenna structures. Should future development make possible the use of longer transmission lines or smaller antennas, the layout of the building itself is such that additional transmitters may be installed by building to either side of the present structure.

The Transatlantic Short-Wave Transmitters

By E. B. FERRELL
Research Department

THE scheme of transmission used in transatlantic short-wave telephony, and the method by which this scheme is carried out, are fundamentally neither novel nor unfamiliar. Carrier power is obtained by amplifying the output from a crystal oscillator and multiplying its frequency, in two steps. The carrier is then modulated by the voice currents, and the resulting radio-frequency signals are amplified in two stages, and finally brought to the antenna where the carrier and both side bands are radiated. But with these fundamentals familiarity ends. The high powers and high frequencies employed have made necessary the design of new equipment and the solution of novel difficulties; a simple example well illustrates the nature of some of these problems.

Everyone believes that Ohm's law holds as well at twenty million cycles per second as it does at twenty cycles per second, but of the validity of this belief it is rather difficult to give any practical demonstration. An ordinary ammeter of the thermocouple type is no longer accurate at these frequencies. But worse than that inaccuracy is the difficulty of placing the meter in the circuit. If it is desired to measure the current in a tuned circuit, the conductor is cut, the meter is inserted and the reading is noted. Probably an appreciable part of the current in question is flowing through some stray capacity and not through the meter. This probability not only casts doubt on the accuracy of the measurement, but raises the question of what current really should have been measured. Almost certainly the insertion of the meter has changed the stray capacities, and the circuit must be retuned. The circuit may not even function as it did before.

Such stray, or distributed, capacities and inductances furnish the problems which, probably more than any other, distinguish the design of short-wave from that of other radio apparatus. This problem becomes more difficult with increase of either power or frequency. Increase in power requires higher voltages and currents, and thus larger apparatus spaced farther apart. The augmented bulk increases both the stray capacities and the unwanted inductance of leads, and higher frequency makes worse their bad effects. From this standpoint, higher frequency and higher power are mutually antagonistic.

The short-wave transmitter now used at Lawrenceville, N. J., on the transatlantic telephone circuit has a power limit of fifteen kilowatts. With the present method of modulation, which is the same as that used by broadcasting stations, this corresponds to sixty kilowatts on the peaks, with one-hundred per cent modulation. That is, a fifteen-kilowatt telephone set of this type could, with proper



Fig. 1—Broadside view of the Lawrenceville transmitter. Left to right: two units for speech-amplification, a unit for radio-frequency generation and modulation, a unit for each of the first stage of radio-amplification, the interstage circuit, and the last stage of amplification, and a double-sized unit for the output circuit. The overall length of the set is as much as three-eighths of a wavelength

power supply, be pushed to sixty kilowatts as a telegraph set.

The idea has been kept in mind that other systems, such as single sideband with suppressed carrier, might be used. For this reason the amplifiers, which could be used with any probable system of modulation, have been extensively developed instead of high-powered oscillators or harmonic generators. The amplifiers have also been made "linear,"* and have been built as a more or less distinct unit, so that they could be used with other types of input equipment employing new systems of modulation. Electrically "last," the amplifiers and their problems will be described first and most extensively.

Across the plates of the amplifier tubes there exist capacities, which are composed of the capacities within the tube, the direct capacity between the tube mountings, and the like. The value of this composite capacity in the first stage is about fifty micromicrofarads. In the last stage, where six tubes are used, it is about one hundred micromicrofarads. This value cannot be appreciably reduced by any change in design which now seems desirable. The reactance of one hundred micromicrofarads at twenty megacycles is about eighty ohms. Thus the designer is faced at the outset with a generator—the tubes—which has an internal impedance of a few thousand ohms, but across whose terminals is strapped an eighty-ohm reactance. This condition is an important limitation in the design of succeeding circuits.

Each short-wave channel operated by the Bell System for transoceanic telephony uses at least three frequencies, covering a range of at least two to one. To cover this range with a single variable condenser would be almost impossible. The initial capacity of the circuit is very high, and placing a variable condenser in parallel with it would only aggravate the condition of low reactance between plates. Moreover, at the voltages

* *The term "linear" is used here not to indicate that the tubes are operated on a linear portion of a dynamic characteristic, but that the output of the amplifier is proportional to the input.*

used, a condenser of any considerable capacity occupies many cubic inches. Instead of changing the operating frequency by a variable condenser, therefore, the coils of each circuit to be tuned to the final operating frequency must be changed for each such major change in frequency.

In the first stage of amplification, the variable element which makes exact tuning possible is a series condenser, inserted in the middle of the inductance. This lowers the net capacity in the circuit, thus permitting the use of larger and more easily constructed coils, and provides a means of coupling to the load of that stage. In the last stage, this series capacity becomes solely a coupling capacity, and the actual tuning is done by means of a short-circuited turn. Because of space and insulation difficulties a turn whose plane could be rotated was not used. Instead, its coupling to the main coils is varied by sliding it up or down, into or out of the field.

Problems of strays arise with inductances as well as with capacities. It is important that various parts of the transmitter be shielded from each other to prevent stray capacities from forming low-impedance feed-back couplings. To this end each stage of amplification, and at high power each tuned circuit, is in a separate shielded compartment. The elements themselves are rather large, and to keep down stray capacities, as well as to prevent actual voltage breakdown, they are spaced well away from the shields. This makes the compartments from twenty-four to thirty inches across. In an early design, the lead joining the interstage tuning condenser to the grid of the last stage was a little over two feet long. With the return circuit, this formed a loop of one or two microhenries inductance, causing serious resonance troubles within the operating range of frequencies. Since this inductance could not be reduced, it was increased a little to form a new mesh in the circuit. The interstage circuit is now a double-mesh circuit, with the variable tuning condenser as the common element.

Singing, the common name for spurious or parasitic oscillations, which caused a considerable amount of trouble in early development, is avoided at the operating frequency by neutralization. At higher frequencies this simple remedy is inefficient, and a very stubborn singing in the neighborhood of seven meters occurs. This has been eliminated principally by introducing resistance components into some of the stray capacities which are coupled to the circuit.

In addition to these two types of singing, there are five other well defined types. They have occurred for the most part in circuits involving choke coils and have been eliminated by the introduction of resistance in such a way as to have a damping effect at the singing but not at the operating frequency.

Although these problems of the amplifiers are aggravated due to the combination of high frequency and high power there, problems of as great difficulty beset the design of the low-powered equipment. An interesting example is that of providing crystal control for the high-frequency carrier.

Since crystals cannot be operated if they are as thin as would be required to give the frequencies used here, thicker crystals of lower frequency are used in conjunction with harmonic generators. The crystal is

of suitable thickness to give three and a third megacycles. The crystal oscillator drives a tube whose plate circuit is tuned to the third harmonic, ten megacycles. The action may be compared to that of driving a pendulum by giving it a sharp blow on every third swing. To gain much amplitude these blows must actually push the pendulum for very short intervals and must be very carefully timed. Electrically, the harmonic generator tube is operated with high grid bias so that current may flow in its plate for only a short part of each cycle of the driving frequency. The plate circuit is tuned in such a way that these short pulses of current flow only for a short part of every third cycle of the output frequency.

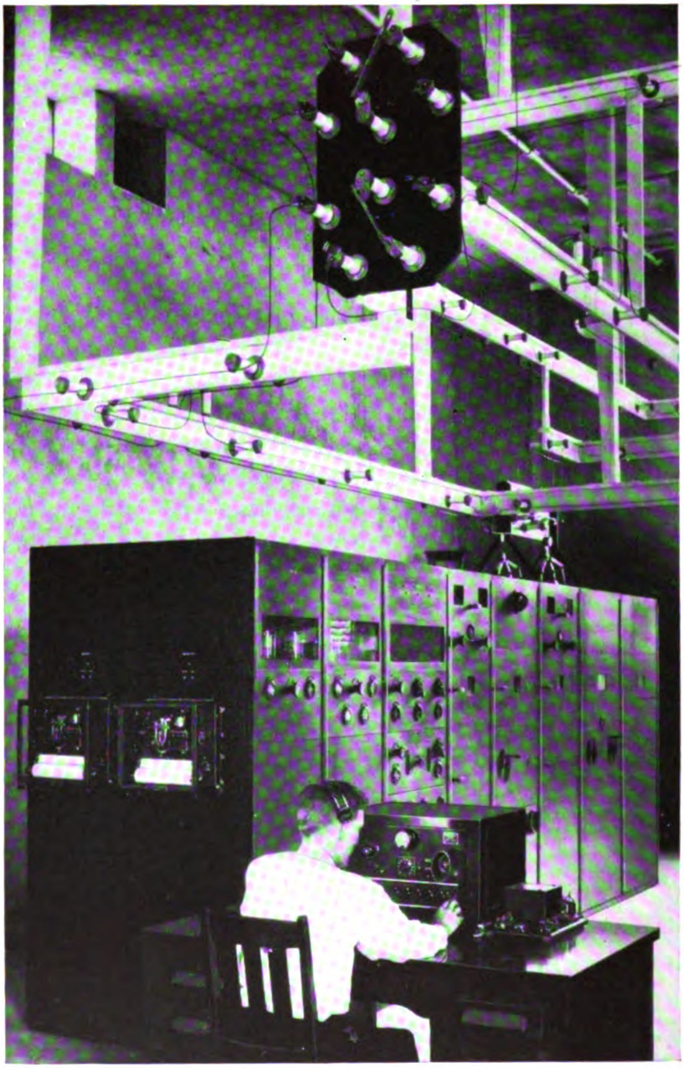


Fig. 2—The transmitter of Figure 1 in the transmitting room of Building A at Lawrenceville

This harmonic generator drives another which doubles the frequency, thus giving a final frequency of twenty megacycles. The plate circuit of this last harmonic generator is also the tuned circuit of a simple push-pull oscillator. Thus, although the oscillator supplies most of the power to this circuit, its frequency is controlled by the harmonic generator and indirectly by the crystal oscillator. The accuracy and stability of the final frequency is then the same as that of the crystal oscillator.

This controlled oscillator is modulated by means of a two-stage speech amplifier. The first stage has a six-hundred-ohm input impedance and uses a fifty-watt tube. The second stage uses four 250-watt tubes in parallel.

The need for simplicity and symmetry

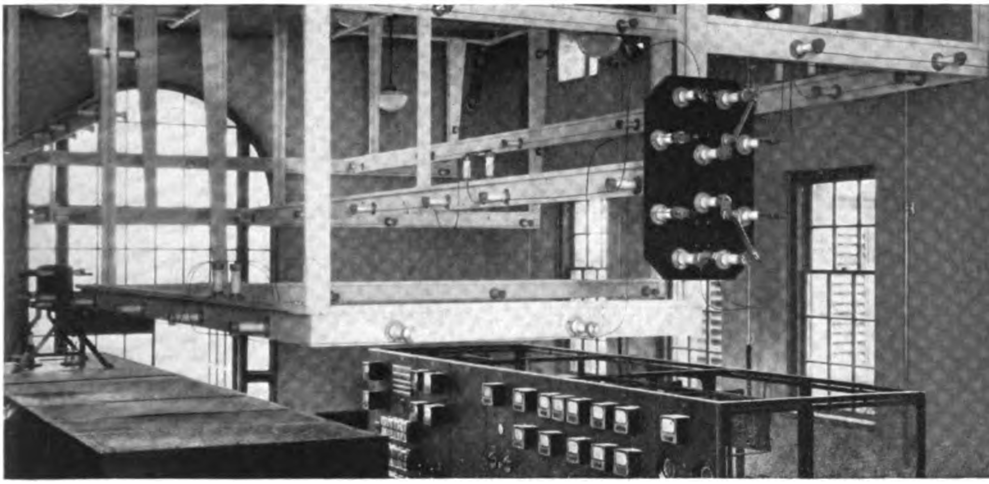


Fig. 3—A corner of the transmitter room

in the radio-frequency circuits has prevented the insertion of ammeters at convenient points, to study the characteristics of the transmitter. For the desired radio-frequency indications, therefore, monitoring rectifiers are used: five-watt tubes, used as two-element rectifiers, with 100,000 ohms resistance in their plate circuits. The high resistance, together with the stray capacities, constitutes a peak voltmeter which has linear characteristics. These radio-frequency voltmeters are used in pairs. The sum of the rectified currents of a pair is most often the reading of interest, but the difference of the two can be used to measure the unbalance of the circuits. A pair is coupled, through small capacities, to the grids of the first stage of high-power amplification, another to the grids of the last stage, and a third to the plates of the last stage.

The monitoring rectifier on the plates of the last stage of amplification is also used to judge the quality of the speech. Since it has linear characteristics, it serves for distortion measurements at audio frequencies. For example, if a pure eight-hundred-cycle tone is impressed on the transmitter, it, together with any of its harmonics which are produced by distortion in the transmitter, will be heard in the output of the monitor. Its amplitude can be measured by a standard audio-frequency measuring set. The ratio of that amplitude, expressed as peak current, to the direct current output of the monitor gives the per cent modulation. The harmonics may be separated by filters and measured, to indicate the amount of distortion. It is found that, when the transmitter is in proper adjustment and the audio-frequency tone is such as to give one-hundred per cent modulation, the distortion products are all as much as twenty-five decibels below the fundamental.

The frequency, twenty megacycles, corresponding to a wavelength of fifteen meters, is mentioned several times in this article, merely as a typical frequency. The sets installed at Lawrenceville will operate within the range of fourteen to forty-five meters with fifteen-kilowatt carrier output.

Short-Wave Transmitting Antennas

By E. J. STERBA
Research Department

THE antenna system is the first object to attract the attention of a visitor to the plant at Lawrenceville, N. J., for the tower line west of Princeton is visible several miles from the station. Upon arriving at the station grounds, the antenna system appears to be a complicated network of wires on rugged towers extending more than a thousand feet past the observer. Appreciating that this extended construction is associated with directive transmission, he may feel that the structure is far too complicated for ready explanation. Yet the fundamentals of directive transmission and thus of the antenna are quite simple.

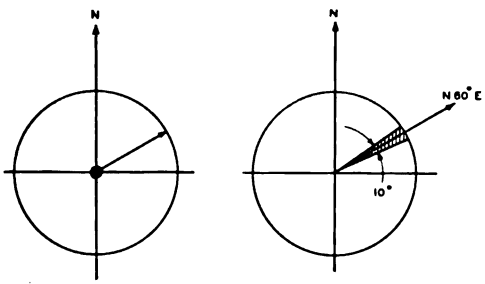


Fig. 1-*A* (*left*)—*Electric intensity about a broadcast transmitter. The area of the circle is proportional to the power radiated; Fig.* 1-*B* (*right*)—*Shaded area represents energy radiated if transmission is confined to a ten-degree sector*

A background of broadcast experience has familiarized nearly everyone with a transmitting antenna. The broadcast antenna is constructed so as to radiate in all directions with equal intensity, because broadcast reception is generally desired in all directions about the station. For this purpose a single vertical wire or several closely spaced vertical wires may be employed. If a vertical-wire antenna is erected upon an ideal transmitting site, the electric intensity in any direction about the antenna and for a constant distance from the antenna may be represented by the radii of a circle (Figure 1-A), signifying equally good reception in all directions about the antenna. The area of the circle is approximately proportional to the power radiated.

If, however, radio transmission is required only between two points, the radiation of energy in all directions other than that in which the receiving station lies is wasted effort. Suppose, for example, that the receiving station is located at N60°E with respect to the transmitter. If some modification is made in the antenna so that radiation occurs only between the radii five degrees to either side of the direction to the receiving station, and if the power of the radio transmitter is readjusted so that the signal-strength from the simple antenna and from the modified antenna are equal at the receiving station, the area of the shaded ten-degree sector in Figure 1-B is proportional to the power radiated—10/360 of that required

for the simple antenna. If this ideal case could be set up, the radio transmitter connected to the modified antenna would consume one thirty-sixth of the power formerly consumed. In telephone nomenclature, an equivalent signal strength would be secured from a source 15.6 decibels lower in power level. It is thus of some economic importance to determine how an antenna may best be modified so that radiation is confined to a narrow sector within which lies the chosen direction.

Heinrich Hertz, who in 1887 and 1888 discovered means for producing and detecting radio waves, constructed the first directive antenna. Employing wavelengths of less than one meter, Hertz experimentally concentrated radio waves in a chosen direction by means of a short antenna lying in the focus of a metallic parabolic surface (Figure 2). In principle the scheme was very much like that of an automobile headlight. Hertz also observed that radio waves of the same length from different sources produced interference patterns—recurring positions of intense and feeble signal-strength—near the sources.

Parabolic reflectors similar to Hertz's experimental antenna have been employed for a number of years in short-wave radio transmission. It is essential that the dimensions of the parabolic reflecting surface be several wavelengths, and hence it is impracticable that the surface be a conducting sheet except for use at very short wavelengths. This difficulty was overcome by using a number of wires, spaced so as to outline the surface, and set at critical lengths so as to be resonant at the operating wavelengths.

Interference, well known with light waves and observed by Hertz with radio waves, is an alternative method for producing directive transmission.* If two or more narrow parallel slit-sources of monochromatic light are directed upon the same surface an interference pattern is produced, visible as a family of light and dark strips. It is brought about by the difference in phase of the radiation from the two

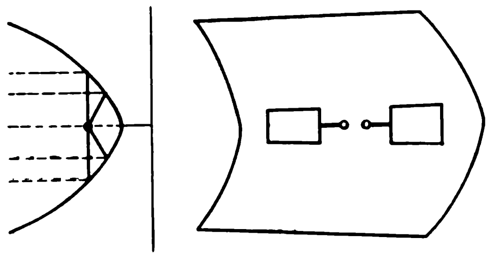


Fig. 2—Parabolic reflector employed by Hertz. The antenna is at the focus of the metallic parabolic surface

sources due to the difference in length of path between the two sources and the screen.

Directive radio transmission by means of wave interference may readily be obtained by transmitting simultaneously from the same transmitter with two or more suitably spaced antennas. If two antennas, one wavelength apart and each carrying unit current, are driven in phase, the electric intensities from both antennas, several wavelengths away in the direction normal to the two, are in phase because the paths from the antennas to the receiving point are equal. The field in this direction is the sum of the fields from the individual antennas. If, however, a direction thirty degrees from the normal is considered, the path from one antenna is one-half wavelength longer than from the other, and the time it consumes

* *The "reflectors" discussed in the preceding paragraph depend ultimately, of course, on interference also.*

in traveling this additional distance puts the radiation from one antenna one-half period behind the other. The intensities in this direction are exactly out of phase and thus the net intensity is zero. By simple trigonometry

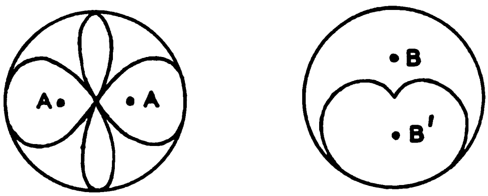


Fig. 3—Directive intensity characteristics for: (A) two antennas spaced one wavelength apart and driven in phase; (B) two antennas spaced one-quarter wavelength apart and driven ninety degrees out of phase (B leads B')

the polar diagram of Figure 3-A may be obtained, representing the intensity in all horizontal directions about the antenna. The radii of the circle enclosing the four-leaf figure represents the intensities which would be realized if the two antennas were very close together.

Forming an example of another simple directive system are two antennas spaced one-quarter wavelength apart and driven ninety degrees out of phase with each other. Since a quarter period is consumed in traveling the distance between antennas, the radiations from the antenna which bears the current lagging ninety degrees will lag an additional ninety degrees upon arriving at the adjacent antenna, and the fields from the two antennas will cancel in this direction. In the opposite direction the fields both lag the same amount and are additive. The polar diagram for this case is given in Figure 3-B, in which again the circle enclosing the figure represents the radiations which would proceed from the two antennas if these were coincident and in phase. It has been found by experiment that two antennas will form this second system if one is driven by the transmitters and the other is parasitically excited. The parasitic antenna is usually called the "reflector antenna."

The above two schemes may be combined in several possible ways to give unidirectional systems. In general the polar diagram of the combined system may be obtained by superimposing the two diagrams and multiplying by each other the lengths of the coincident radii to obtain the lengths of the new radii.

Simple directive systems, such as

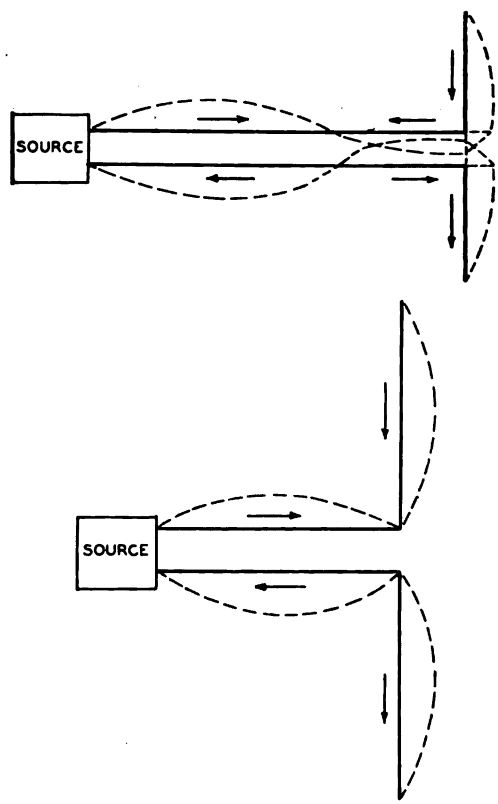


Fig. 4-A (above)—Line bent into a Hertz antenna; Fig. 4-B (below)—Line bent into two Hertz antennas

those described, were proposed by S. G. Brown in 1899 and J. S. Stone in 1901, and many others have since devised increasingly complex and more efficient schemes. Later G. A. Campbell, of the American Telephone and Telegraph Company, proposed a directive scheme comprising several rows, each bearing several antennas in suitable phase relations. He established in a general manner the relations between the spacings and phasings and devised methods whereby the performance of the system, however complex, could be predicted.

In the polar diagrams, the area of the figure, as compared to the area of the enclosing circle, is approximately proportional to the relative power consumption of the directive and the non-directive systems and thus an approximation of the gain of the directive system may be obtained by expressing the ratio of the areas in transmission units. The reason for this gain may be suggested by another simple example. If two antennas, several wavelengths apart, each have a resistance R and carry a current I, the total power consumed is $R\ I^2 + R\ I^2 = 2\ R\ I^2$. The intensity at a point where the radiations are in phase is proportional to 2 I. This same intensity could be obtained by exciting one antenna alone with 2 I units of current but the power consumption would then be $4\ R\ I^2$, or twice as much as before. In general the improvement factor of a directive antenna is nearly proportional to the number of antennas, when they are separated by more than about one-half wavelength. This is only approximately true because two antennas, when close together, react upon each other.

There are many methods for the mechanical construction of directive antennas; that now being employed at Lawrenceville depends upon the manner in which waves stand upon transmission lines. It is generally known that the current in an open-circuited line recurs along it in standing maxima

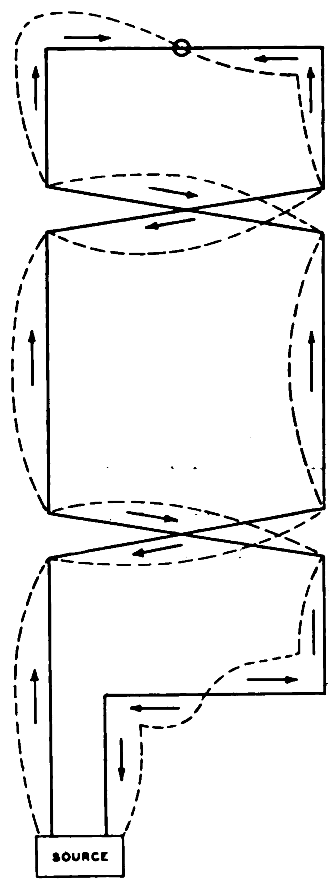


Fig. 5—A panel for the Lawrenceville antenna system. The vertical members are radiators; the crossed members are transmission-line phase shifters. The line may be open or closed at the center of the top cross-piece, since there is a standing-wave node, and thus no current flow, at that point

and minima, that the phase difference between successive current maxima is 180 degrees and that the phase difference between corresponding points



A part of the line of towers supporting the antennas

on the two wires is 180 degrees. The radiation from an open-circuited line is small, but if the ends of the line are bent outward, the radiation from these ends will be greatly augmented and the balance of the line will act largely as a means for transmitting power to the radiating end. If the bent portions are each one-quarter wavelength long, a one-half wave Hertz antenna is formed (Figure 4-A). An even more efficient antenna may be formed by bending over a one-half-wave portion of the line; in this case the bent-over portion is equivalent to two Hertz antennas driven in phase (Figure 4-B).

Thence it is only a small step to the panel arrangement of the Lawrenceville antenna system (Figure 5). Here the vertical wires are the radiating members, all excited in phase, and the horizontal pairs are transmission lines for distributing the current to the radiating elements in the desired phase-relations. The panel is equivalent to four Hertz antennas, two of which are stacked one above the other and of which the two groups thus formed are spaced one-half wavelength apart. Complete reinforcement of signal intensities takes place only in the horizontal direction normal to the panel. In all other directions destructive interference occurs; complete cancellation occurs in the plane of the panel.

By computation and by experiment it has been shown that a power improvement of four decibels is acquired from the horizontal spacing of one-half wavelength, and of two decibels from the vertical stack of two. The net power saving is approximately six decibels: the panel consumes but one-fourth the power which would be re-

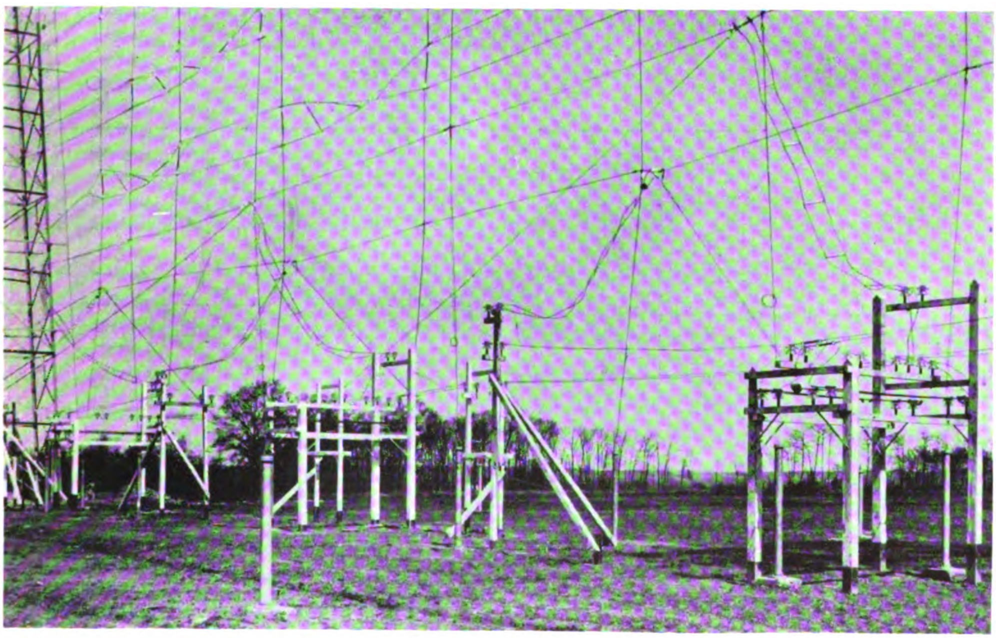
quired by one element to produce the same intensity in the chosen direction.

A second similar panel, excited parasitically, is placed one-quarter wavelength behind the first to act as a reflector and thereby create an unidirectional system. It has been found that the reflector reduces the power required to maintain a given intensity in the desired direction by approximately three decibels, and thus brings the gain of the two-panel system up to nine decibels. The two-panel system, therefore, requires but one-eighth the power which would be necessary in a simple antenna producing the same intensity in the desired direction.

Larger power savings may be effected by employing many antennas properly connected together. Practically, however, considerations of mechanical construction, investment and maintenance limit the size of the system. The complex nature of short-wave transmission also leads to a lowering of the optimum size of the antenna. For wavelengths of the order of sixteen meters, improvements of twenty decibels (a power ratio of one hundred) are practicable.

The connection of a number of antenna panels to a common feeder line must accomplish proper phase and impedance relationships. The former may readily be obtained through adjusting the lengths of interpanel lines, by tape-line measurements. The conventional methods for building up the load impedance to the surge impedance of the feeder line, however, are far from satisfactory for high-power work at short wavelengths. In this case one of the less familiar properties of a transmission line is used for transforming impedances.

If a line of surge impedance Z_o, exactly one-quarter wavelength long, is terminated with a load Z_R, the



Lower edge of antenna curtain, and frames supporting the quarter-wave lines for effecting sleet-melting connections and proper terminating impedances

sending-end impedance of the line is $Z_0{}^2/Z_R$ and, if Z_R is a pure resistance, the sending-end impedance is a pure resistance. Such a quarter-wave line is employed in the Lawrenceville antenna system. Since a line bearing standing waves is being terminated at one upon which standing waves are not desired the receiving-end of the quarter-wave line is connected at either a current maximum or minimum, to ensure a resistance load.

A transmitting antenna is adversely affected both mechanically and electrically by sleet. The sleet load may strain the system to the breaking point and thus put the antenna out of service for a long period, and the mass of ice, having a dielectric constant of eighty, may detune the antenna and destroy the effectiveness of the system. Sleet is, therefore, removed in the Lawrenceville system, by heating

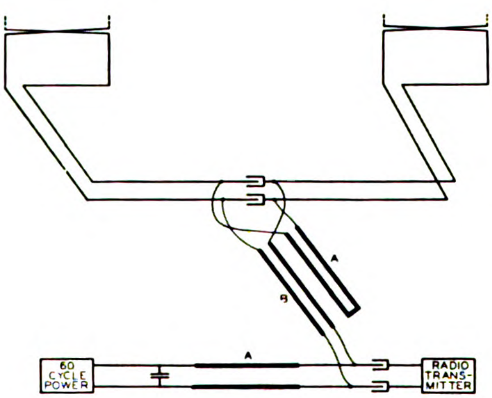
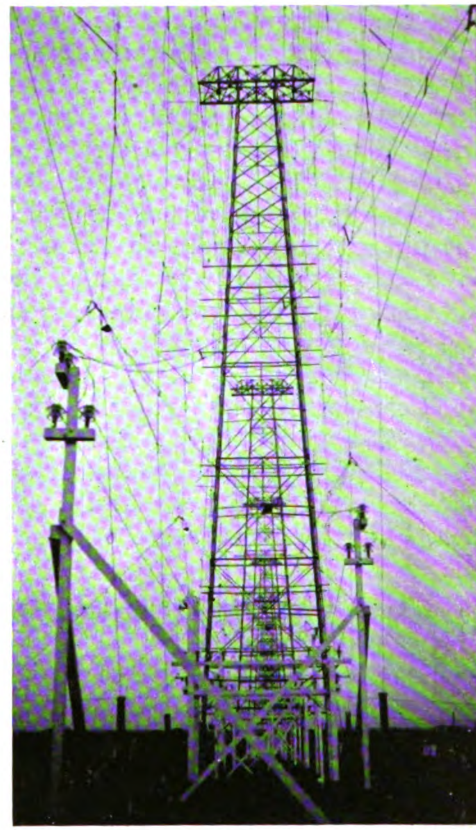


Fig. 6—Antenna connections for melting sleet from the Lawrenceville antenna

the wires with low-frequency currents of about 150 amperes at a potential of nearly a thousand volts in each antenna. All elements in the antenna are arranged to be in series for the low-frequency currents and the vertical elements in phase for the radio-frequency currents (Figure 6).

Another relatively unfamiliar property of transmission lines is utilized to effect this arrangement. If a line one-quarter wavelength long is short-circuited at the receiving end, the sending-end impedance is very large. Such



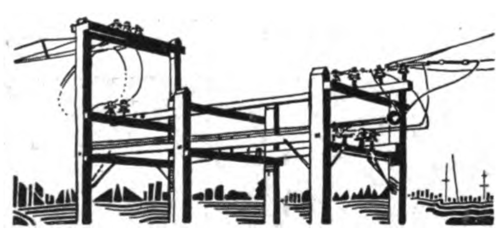
Looking down a tower line at Lawrenceville. Photo by G. M. Eberhardt of the Research Department

a line may be connected across a circuit of relative low impedance without disturbing its radio-frequency functions. From Figure 6 it may be seen that the anti-resonant circuit of quarter-wavelength bars, in combination with several condensers which readily pass radio frequencies but which block low frequencies, and in combination with two antenna panels, forms a series

circuit for the low-frequency currents and the power source. The two panels, however, are in parallel with each other and with the feeder line at radio frequencies. Both the low and the high-frequency powers may be applied simultaneously to the antenna.

For three of the four communication channels at the Lawrenceville radio plant, the antenna system is supported by a row of nineteen towers at right angles to the direction of England; for the fourth, a row of seven towers is placed at right angles to the direction of Buenos Aires. Guys run along the tops of these towers to anchors on the ground at the ends of the rows. The towers, 250 feet apart and 180 feet high, are designed to withstand the load of the largest antenna that can be supported in a bay, when covered with a coating of ice one-half inch in radius and subjected to a gale of ninety miles per hour. Each antenna occupies two tower-bays. The antenna-curtains themselves are supported by messenger cables and may be lowered or hoisted by individual winches; the curtains are constructed from No. 6 B & S wire and are held in position by insulated sections of steel harness. The several panels in each curtain are interconnected by transmission lines which lead to frames where proper connections are made and impedances built up to terminate the power leads from the radio transmitters.

The practicability of directive systems is dependent upon the shortness of the transmitted wavelengths. A twenty decibel antenna, operating on five hundred meters, would be approximately ten wavelengths or fifteen thousand feet long and two wavelengths or three thousand feet high. The investment in such a plant would probably never return dividends. Fortunately the wavelengths used in the transoceanic short-wave system are such that directive effects can economically be obtained.



The Transatlantic Short-Wave Receivers

By F. A. POLKINGHORN
Research Department

THE function of the radio-telephone receiver is to select the desired signal, to amplify it, and then to detect or demodulate the signal so that its voice-frequency components may be sent over a telephone line to a subscriber.

The problem of selecting the desired signal to the exclusion of others is a major design problem. A directive antenna system serves to discriminate to a considerable extent between signals arriving from different directions, but to only a slight extent between the desired signals and others closely adjacent in frequency. The receivers built for the short-wave transoceanic channels are of the double detection or "superheterodyne" type. This type was chosen because it is well adapted to give a high degree of selectivity desired, and to provide the large amplification required with a minimum of trouble from regeneration or singing.

Each transmitter and receiver of the transatlantic circuits must be capable of operating on any one of three frequencies in the range between 9,000 and 21,000 kilocycles in order that the operators may pick a frequency upon which transmission is good at any particular time. At the receiving station each receiving unit consists of three antennas and a receiving set. The antennas are located several hundred feet apart so that they do not influence one another. At each antenna there is a circuit which aids in obtaining the desired direc-

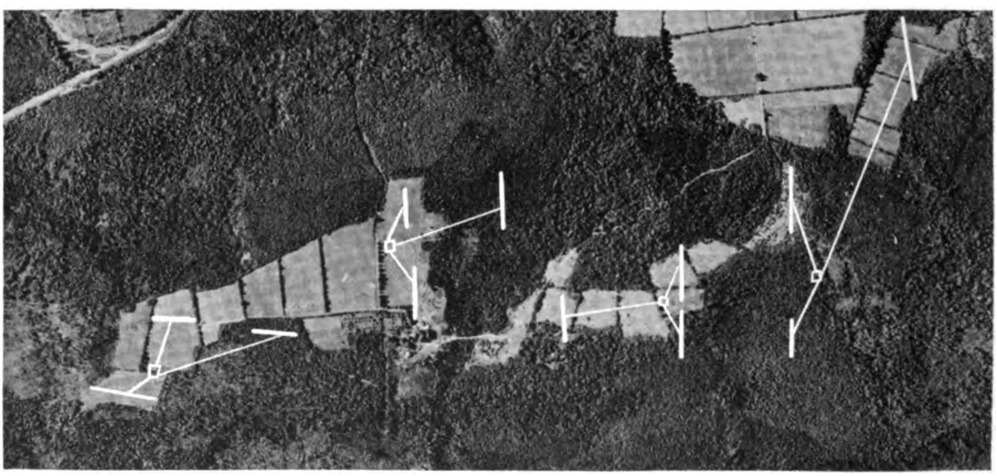


Fig. 1—Airplane view of Netcong, N. J., showing locations of receivers (as white squares), antennas (as heavy white lines), and antenna transmission lines (as light white lines)

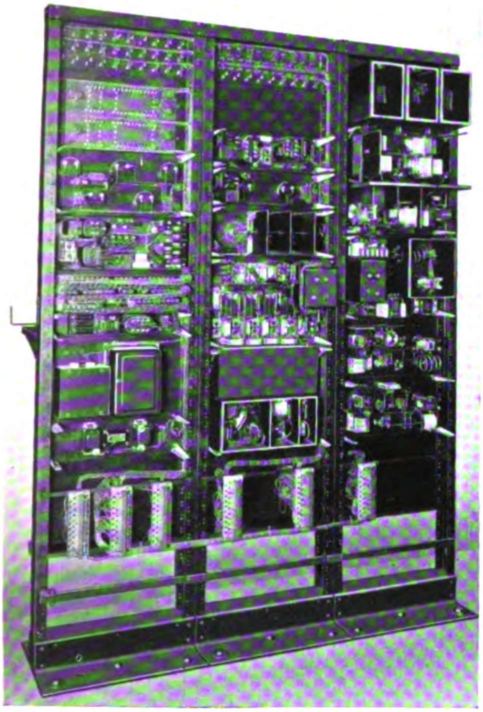


Fig. 2—Rear view of a receiver

tional characteristics from the antenna and acts as a transformer to connect the antenna to the transmission line leading to the receiver. This transmission line, formed by copper tubes, one within the other and separated by insulating rings, is supported a few inches above the ground. It follows a sinuous course, with bends to allow for expansion and contraction under temperature changes.

The receiver has three antenna circuits which are always connected to their respective antennas and to the grids of three screened-grid vacuum tubes of the 246-A type. A switch in the plate circuits of these tubes determines which of the antenna circuits is to be used at any one time. An additional stage of screened-grid amplification is then used.

The incoming signals next reach the first demodulator where they are combined with another frequency such as will give a beat, or intermediate, frequency of 400,000 cycles. For example, if it is desired to receive a frequency of 18,310 kilocycles, the beating oscillator of the receiver is adjusted to either 17,910 or 18,710 kilocycles. Either of these frequencies when combined with the received frequency of 18,310 kilocycles gives a beat frequency of 400 kilocycles. This intermediate frequency is then passed through a narrow band-pass filter. Six additional stages of amplification

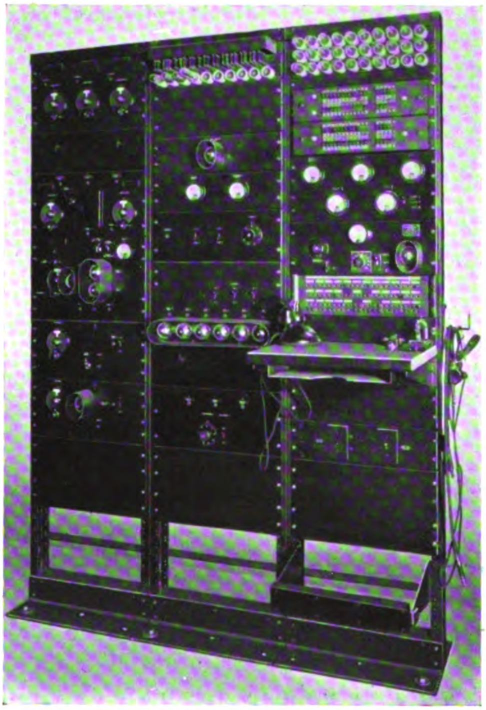


Fig. 3—Front view of a receiver

follow the filter. An attenuator is inserted between the first and second stages for control and measuring purposes. Another band-pass filter is used to connect the last amplifier to the second demodulator, where the speech frequencies are reproduced.

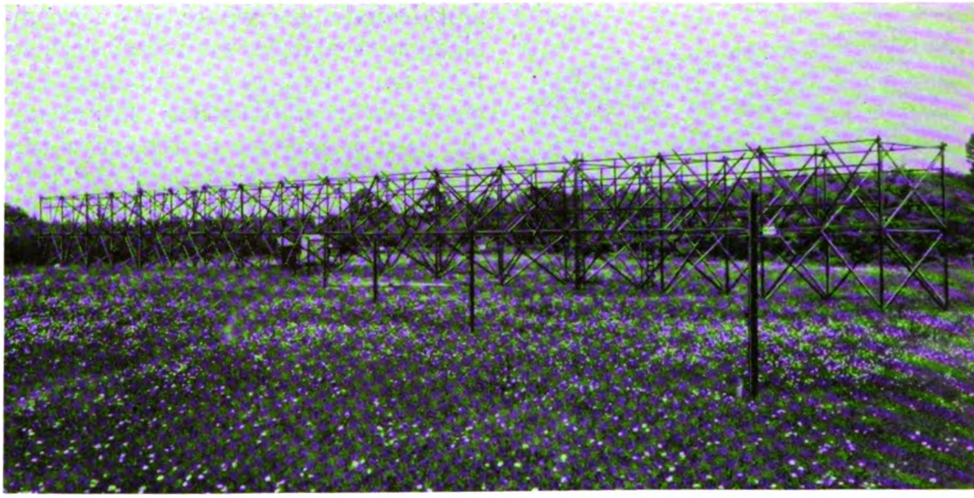


Fig. 4—General view of a receiving antenna

One stage of voice-frequency amplification brings the speech-level to that required for transmission over the cable to the central terminal building, where the speech is further amplified and sent over the line to the transatlantic operator in New York.

When received at any single point, waves of the frequencies used on these channels are subject to wide fluctuations of intensity, probably because the waves proceed over several different paths to the point, and there aid or oppose each other in a random manner.* This fading causes the voice-frequency output of the receiver to vary somewhat periodically at frequencies between once every few seconds and many times a second. Such changes in volume are quite disconcerting to a subscriber and consequently an automatic gain control has been included in the receiver to minimize this trouble.

The automatic control acts to change the gain in the receiver in inverse proportion to the strength of the received signal, thus causing the output level to remain substantially constant. This is accomplished by using an additional amount of intermediate-frequency amplification in an auxiliary amplifier, rectifying the output of this amplifier and applying the rectified output voltage as additional bias on the grid of the first demodulator. An increase in the received signal tends to increase the output of the rectifier which, when applied to the grid of the first demodulator, decreases its efficiency and greatly reduces the rise in output volume of the receiver over what would otherwise be obtained.

The appearance of these receivers is quite different from the ordinary receiver used for broadcast reception. Since the receivers are an integral part of the telephone plant, standard telephone construction was used as far as was practical. All apparatus is mounted on brass panels which are in turn mounted on relay racks. The panels are faced with mats of furniture steel to hide the numerous screw holes necessary for mounting

* *H. T. Friis,* Bell Laboratories Record, *July,* 1928.

the many small parts in place. Fuse panels provide protection for all plate and filament circuits. In addition each plate circuit is provided with a protective lamp.

Any filament or plate current may be read by inserting a short-circuiting plug into the corresponding jack in a jack strip, and thus connecting one of the meters on the meter panel into the circuit through an auxiliary fuse. This means may be used to keep the set in operation while replacing a fuse. A dummy plug placed in a jack will open its circuit; an external meter may be plugged into a circuit by means of a cord.

Telephone and telegraph facilities for use of the operator are mounted directly on the set. Head receivers and a monitoring coil are provided so that the operator may monitor the circuit when required. A volume indicator is constantly connected across the output of the voice-frequency amplifier. By observing the volume indicator and the meters connected in the second demodulator and rectifier a good idea of how the set is operating can be obtained at any time. A high-frequency oscillator and an intermediate-frequency oscillator are included in the receiver so that the set may be completely adjusted, and the adjustments be readily checked, without the aid of a received signal.

For all tubes "filament-failure lamps" are provided, which give a red indication when a filament fails. Since there are a large number of tubes of four different types in the set, a name plate is used to designate each tube position and the type of tube to be used in that position.

Shielding, to prevent regeneration in the high-frequency and auxiliary gain-control amplifiers, is provided by the mats, parts of which are hinged on certain panels to form doors opening into compartments behind the panels where the tubes and circuits are placed. Throughout the design of the receiving equipment every effort has been made to ensure convenient and reliable operation in routine commercial use.



Short-Wave Receiving Antennas

By E. BRUCE
Research Department

IMPROVEMENTS in any point-to-point radio system should be made first at those places where a given overall result is least costly to secure. In particular the effect of increasing the power of a transmitter can equally well be secured by improving the effectiveness of either the transmitting or the receiving antenna. The expense of high-power transmitters is very great, and the designer of receiving antennas can command a considerable working budget without being underbid by the designer of transmitters.

The design of receiving antennas is important for other reasons as well. An apparently irreducible minimum of noise is inherent to the input circuits of the first vacuum tube* of the radio receiver. To override this noise, increased antenna efficiency, through directivity, becomes the most fruitful means of increasing the signal "pick-up." When static rather than internal noise is the limiting factor, antenna directivity again accomplishes an improvement. Signal waves come from a rather definite direction toward the receiver; static disturbances, on the other hand, come from nearly all directions at random. The directional receiving antenna, responsive only in the direction from the transmitter, takes full advantage of the desired signals, but discriminates against all static disturbances except those which approach the antenna from the responsive direction.

An antenna will develop directional properties if it is built up of distinct wire-segments or "elements," and if these elements are spaced apart by a suitable and fairly large fraction of the wavelength of the signal which the antenna is expected to pick up. Only with the use of "short waves" did it become economically practicable to build systems large enough compared with the wavelength to take advantage of this directivity. The short-wave transatlantic antenna employs a row of equi-spaced elements, identical in their phases and power levels. This form of antenna is often termed "broadside," as it is maximally active to waves proceeding perpendicularly to the row of elements.

There are numerous ways of so interconnecting spaced elements as to obtain specified phase and power relations; the way most suitable for commercial use is, of course, that which necessitates least adjustment and which accomplishes the desired directivity with the simplest structure. A long wire can be folded back and forth in space in a simple manner to give the desired phase relations for "broadside" directivity. If the attenuation along it is negligible, the elements will all have equal power levels with reference to all points of the antenna.

* *The cause and effect of the random voltage fluctuations which occur in resistances are discussed by J. B. Johnson in the* RECORD *for February, 1927.*

Such a structure is shown in Figure 1. The lengths of the vertical elements, and the spaces between them, are one-quarter of the length of the signal wave which the antenna is expected to pick up. Such a wave, traversing the antenna, induces in the vertical elements voltages which are equal but whose phase relations depend on the direction of approach of the wave. In analyzing the behavior of the antenna, these electromotive forces may be represented by lumped voltages at the central points of the verticals.

Each lumped voltage can be supposed to cause in the wire a succession of electrical disturbances whose sense and magnitude depend on the sense and magnitude which the voltage has at the successive instants. The disturbances successively originated at a voltage source can be regarded as passing out along the wire in both directions from the voltage source, as two trains of disturbances which retain their senses and magnitudes. The passage of such a train constitutes a current. When two currents passing in the same direction are composed of disturbances which correspond in sense at all points, the two reinforce each other. When, however, the disturbances composing two currents passing in the same direction are of equal magnitudes but opposite senses, the two cancel.

Thus from each source of voltage electrical disturbances will pass both to the receiver and to the open end of the antenna. Those proceeding to the open end will be reflected there and will thence in turn pass, with magnitudes unchanged but with senses reversed, to the receiver. Maximum reception will occur when the signal wave approaches in such a direction that the voltages it induces in the antenna produce disturbances which are additive on reaching the receiver. No reception will occur when these disturbances cancel at the receiver.

When the signal wave is proceeding broadside to the antenna, it induces in the vertical elements voltages which are identical in phase from the

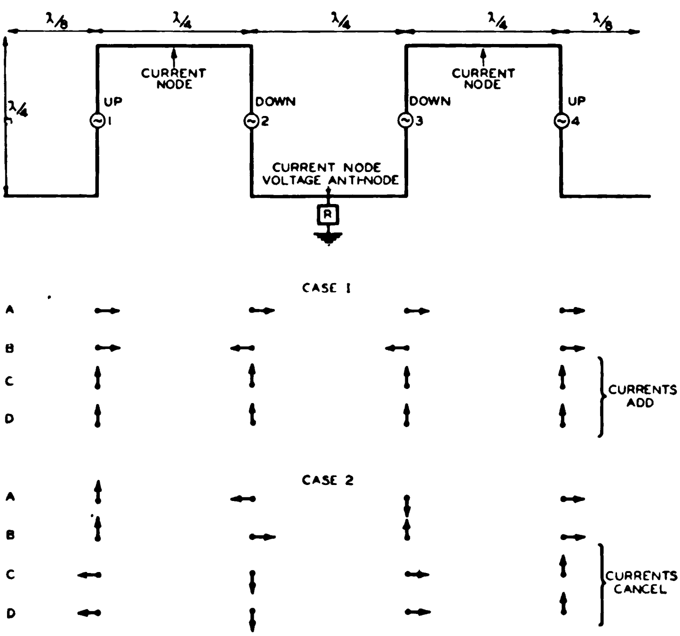


Fig. 1—Behavior of broadside antenna to broadside (Case 1) and end-on (Case 2) waves. The vectors are drawn below the elements whose electrical effects they represent. A—space voltages; B—wire voltages; C—currents in R (directly propagated); D—currents in R (by open-end reflection)

standpoint of the plane of the verticals. Figure 1, Case 1, shows in row A voltage vectors drawn below the elements to represent the voltages at a particular instant. The manner of connecting the verticals, however,—alternately at their upper and lower ends—vitally distinguishes between the voltage phases viewed from the plane standpoint and from the wire standpoint. When the vertical elements and their horizontal connections are regarded as one continuous wire, the folding in space effectively alternates the voltage phases of the successive vertical elements of the wire, for either side of the receiver R. These voltage vectors are shown in row B.

At each source of voltage, similar voltage vectors recur with a frequency equal to that of the incident wave. Since one wavelength is the distance between sources of voltage whose voltage vectors are simultaneously similar, each disturbance propagated in either direction arrives at the next similar voltage source exactly one cycle later. Thus the disturbances propagated in either direction reinforce one another. The currents proceeding toward the receiver do so in phase and produce an additive effect. Their current vectors appear in row C. Those proceeding toward an open end likewise do so in phase, and are there reflected back toward the receiver with their component disturbances reversed in sense. Since the total current reaching the open end travels a quarter-wavelength from the last voltage source to the end and an equal distance back to that source again, a half-cycle elapses between the two visits. But the reflected current of reversed disturbances finds there on its second visit a reversed voltage, propagating a reinforcing current The reflected currents, therefore, proceed toward the receiver in phase with, and thus adding to, the directly propagated currents. These current vectors appear in row D. Altogether it is evident that the antenna is in this case making the most of all its currents for the benefit of the receiver.

When, as in Case II of Figure 1, the wave approaches the antenna end-on—at right angles to the broadside wave of Case I—the antenna acts with very different effect upon the receiver. In Case I any one part of a signal wave traversed all elements of the antenna simultaneously; in Case II it traverses them successively. Alternate sources of voltage, which are a half wavelength apart in space, are a full wavelength apart along the wire. Thus any part of a signal wave which has induced a voltage in an element will reach the next-element-but-one through space a half cycle before the disturbance it caused in the first element, proceeding in the same direction, can reach the new element through the wire. The disturbance proceeding in the opposite direction will reach the next-element-but-one a cycle and a half after the part of the wave which produced it has passed that element. This is the time of the signal in advancing a half wavelength through space plus the time of the disturbance in returning a full wavelength through the wire. When either disturbance reaches the next-element-but-one from its source, a later part of the signal wave will be inducing an equal but opposite voltage in that element. The resulting disturbance will be equal and opposite to the arriving one and will cancel it. All currents, therefore, in either direction in the antenna will annul one another, so

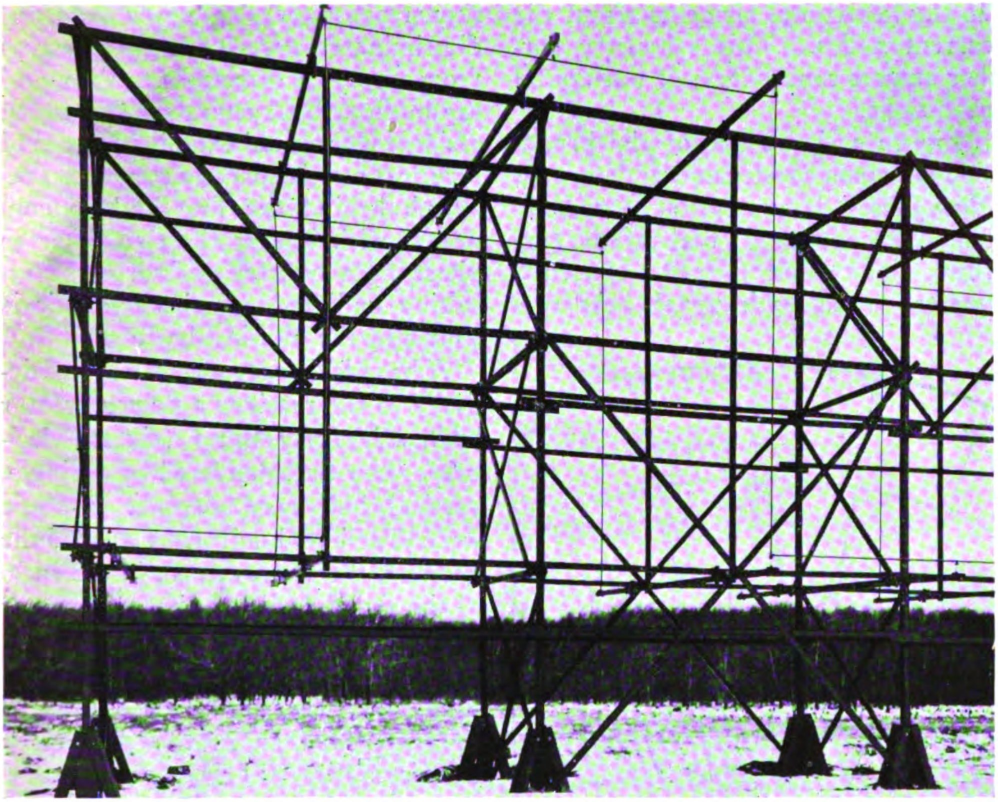


Fig. 2—One end of a short-wave directional receiving antenna at Netcong, N. J.

that the receiver will not be energized.

This antenna, accordingly, has maximum sensitivity to a broadside wave (from either direction) and no sensitivity to an end-on wave. To waves of intermediate direction it has intermediate sensitivity. Relative sensitivity can be plotted against direction in a polar diagram to show the sensitivity-characteristic of the antenna.

A valuable feature of this antenna is that it does not permit the currents induced in its vertical elements to suffer loss through reradiation from its horizontal elements. Such loss could be accomplished only by the passage of the currents along the horizontal connections. Due to the plurality of voltage sources, the electrical disturbances add in such a way that the current is in standing waves. Fixed current nodes occur in these standing waves at each multiple of a half wavelength measured from the open end: at the centers of the horizontal elements. Thus the net value of current in each horizontal is small at all times and is composed of disturbances which at either side of the node are opposite in sense. In directions perpendicular to the horizontals the radiations from the opposite currents cancel, at any appreciable distance. In other directions the fact that the currents are small and opposite makes radiation negligible. The symmetry of the antenna either side of R, moreover, causes the antenna to act as a whole about R in the same manner as

do the horizontal elements about the current nodes. This symmetry further assures cancellation of horizontal radiations.

Figure 2 shows one of the broadside antennas constructed at Netcong, New Jersey, for reception from England. It contains, in each of the two rows, twenty-four elements spaced a quarter wavelength apart. As was shown before, a single row does not discriminate between broadside waves from opposite directions. To avoid the bi-directional characteristic which a single row would exhibit, the second identical row is spaced a quarter wavelength behind the first and so connected with it that the two differ in phase by a quarter period. The resulting undirectional characteristic is shown by the plot in Figure 3.

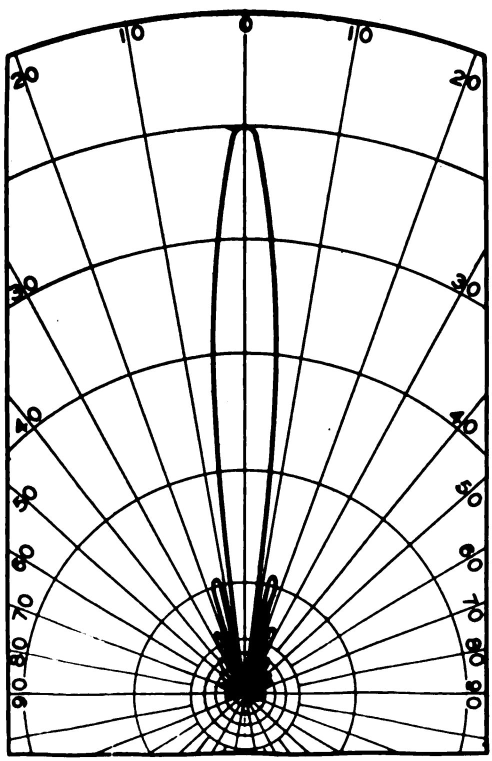


Fig. 3—*Directional characteristic of Netcong antenna*

A broadside antenna of this size delivers to the receiver a power greater by nearly forty times (sixteen decibels) than that delivered by a single, vertical, half-wave antenna. If static were distributed uniformly around the antenna, the improvement in the ratio of the signal power to the static power would likewise be nearly forty fold. When discrimination against directional static can be effected by use of the deep minima in the directional characteristic, still greater improvements in the signal-to-static ratio are possible. The variability in the apparent direction of received waves* is of course a major factor in limiting the degree of directivity which it is useful to attempt. Within this limitation directional receiving antennas accomplish great increases in the efficiency of point-to-point radio systems operating on short waves.

* Bell Laboratories Record, *July*, 1928, *page* 359.

NEWS

and Pictures of the Month

including

Notes of the Club



Twenty years ago William Fondiller—Assistant Director of Apparatus Development—came to the Laboratories with a letter of introduction from Michael I. Pupin. Within his organization are three other men—W. J. Shackelton, H. H. Glenn, and J. C. Wright—who also completed twenty years' service in July

On the morning of July twelfth, R. L. Jones presented the 20-year service buttons to these four men in Mr. Fondiller's office and later in honor of the occasion entertained the group at an informal luncheon

News Notes

THE EMPLOYEES' Benefit Committee has been delegated authority by the Board of Directors to bridge automatically all breaks in Bell System service of members of the Laboratories, when they complete ten years of continuous service before reaching the age of sixty-five years. The only exceptions are breaks which occur before the completion of six months of continuous service.

The Committee also has been authorized, at its discretion, to bridge, before ten years of continuous service have been completed, any break occurring for educational reasons, and any break of less than six months which occurs after the completion of six months of continuous service. Except in case of breaks for educational reasons, the discretionary authorities of the Committee will be used only in unusual cases after a thorough investigation of all the facts.

A. F. Weber, the Secretary of the Committee, will notify those members of the Laboratories who are affected, as soon as adjustments of their service records have been made.

* * * *

DURING the past year some four hundred members of the Laboratories have continued their studies through courses in one or another of the night schools of greater New York. Of this number about half are studying for a degree; and ten, shown in the accompanying photograph, received bachelor degrees this year.

At the Polytechnic Institute of Brooklyn, S. F. Farkas was awarded a Summa Cum Laude, an honor incorporated in its curriculum only this year; but a search of the records indicated no previous candidate with equally high average grades.

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THE SIXTEENTH meeting of the Telephone Pioneers of America will be held at Minneapolis on October 18-19.

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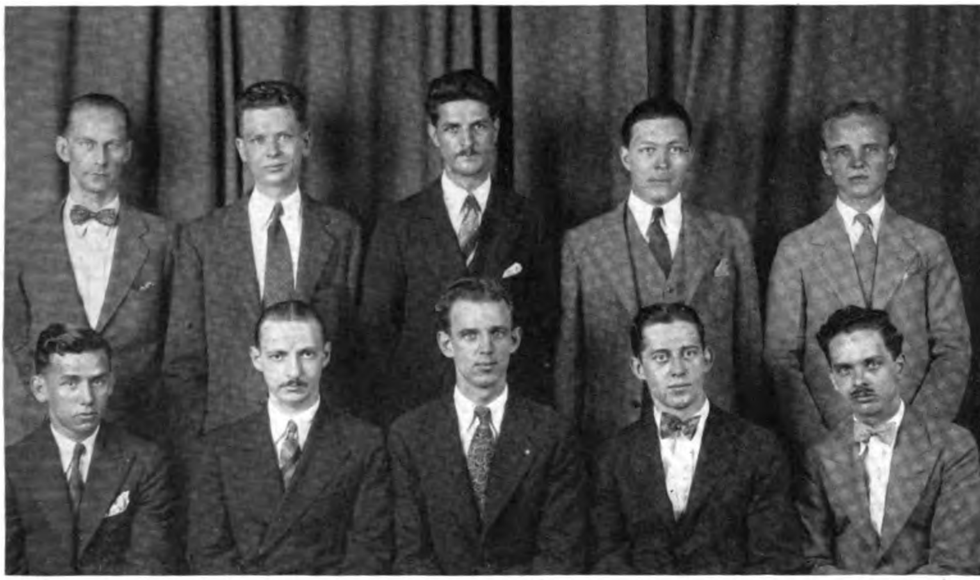
S. P. GRACE has returned from a two months' tour of the Pacific Coast where he delivered a number of lectures before various scientific and technical bodies. Great interest was shown in all of these talks. The attendance, mounting to several thousands in many instances and filling the halls to the overflowing, far exceeded any of the previous meetings held during the year by the societies. R. M. Pease was in charge of the demonstrations given at each of these lectures.

SYSTEMS DEVELOPMENT

H. M. SPICER visited the Palmer Electric Company at Waltham, Massachusetts, to discuss proposed modifications in the design of the Palmer master switch used in panel machine switching.

C. BORGMANN went to Cincinnati for the purpose of investigating ringing conditions on switchboard cable.

H. D. BRUHN spent several days at Wilmington, Delaware, and James-



Receiving bachelor degrees this year from night schools in the vicinity of New York are: standing, left to right—J. H. Bullwinkel, R. C. Williams, E. A. Krauth, M. A. Warren, and S. F. Farkas; seated—E. F. Ennis, G. Gottron, W. Kalin, O. C. Bleicher and J. R. Hefele

town, New York, in connection with PBX problems.

CONFERENCES with Western Electric engineers required the presence of J. Irish and C. H. Achenbach in Hawthorne during the past month.

H. A. MILOCHE was at Cleveland to confer with engineers of the Ohio Bell Telephone Company on various projects concerned with the new Akron Toll Office.

DURING THE month F. S. Kinkead, H. H. Spencer, J. H. Sale, R. P. Jutson, and W. E. Burke visited Durham and Greensboro, N. C., and Greenville, S. C., to observe trial installations of recently developed apparatus on toll repeater stations.

L. M. ALLEN was at Chicago to observe the installation of the 701-A PBX at the joint warehouse of the Western Electric and Illinois Bell Telephone Company. While at Chicago he visited the Hawthorne plant and later on the same trip visited Detroit, Jackson and Kalamazoo in connection with toll line dialing matters. He also stopped off at Cleveland for the purpose of undertaking circuit studies.

A TRIAL INSTALLATION of toll line dialing between Kalamazoo and Detroit, Michigan, was observed by L. M. Allen and J. Meszar.

C. W. GREEN, R. W. CHESNUT and J. A. MAHONEY went to Washington to view a new automatic pilot channel for carrier telephone systems. Tests along the line of this installation between Washington and Jacksonville are being made by W. F. Kannenberg, D. M. Terry and C. M. Hemmer.

R. A. LECONTE visited Allentown, and D. T. Osgood, Bedford, Pennsylvania, where tests are being made on program transmission over cable circuits.

A. F. BURNS, C. H. BIDWELL, J. M. DUGUID and C. W. VAN DUYNE

visited Springfield, Massachusetts, and Syracuse, New York, where improved methods of supplying central-office tones are being tested.



W. J. Lacerte and E. J. Donohue visited Syracuse, New York, where an improved out-trunk preselector is being tested. Mr. Lacerte also visited Gary, Indiana, where a newly devised number checking arrangement is under investigation.

M. E. Krom spent several days at Ellenville and Penn Yan, New York, on a study of subscribers' line ringing positions.

H. E. Powell visited Jamestown, New York, where improved rural line service is under investigation.

V. T. Callahan and F. F. Siebert have been at Cincinnati to investigate an improved method of starting gasoline engines.



B. M. Bouman visited Gardner, Massachusetts, and Chicago on work connected with various improvements on operators' chairs.

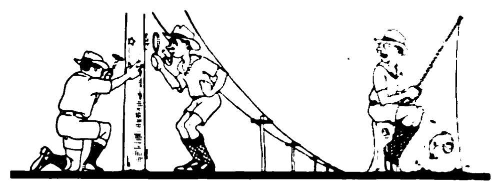
Patent

The Patent Department reports that E. W. Adams, W. C. Kiesel, E. C. Laughlin, I. A. McCorkendale and G. H. Stevenson were at Washington and J. G. Roberts was at Chicago in connection with the prosecution of patents during the period from June 7 to July 5.

Outside Plant Development

R. H. Colley visited the Forest Products Laboratory at Madison, Wisconsin, and conferred with members of the staff in regard to standard fiber strength values for poles.

In connection with studies of preservative treatments on poles, particularly lodgepole pine poles, G. Q. Lumsden, D. C. Smith of the American Telephone and Telegraph Company, and R. W. Lindsay of the Mountain States Telephone and Telegraph Company made an inspection tour of pole lines in Montana and Wyoming. C. H. Amadon was at Denver and Salida, Colorado, during the greater part of June to observe these preservative treatment methods.



C. D. Hocker, C. S. Gordon, F. F. Farnsworth and E. M. Honan attended the annual convention of the American Society for Testing Materials at Atlantic City.

F. F. Farnsworth has been in Florida to observe the wearing qualities of various paints used on Bell System motor vehicles.

C. S. Gordon's work on drop wire production took him to the plant of the New York Insulated Wire Company at Wallingford, Connecticut, to observe manufacturing methods. While on this visit he went to the Reliable Manufacturing Company's

plant at New Haven to investigate the manufacture of strand dynamometers.

Inspection Engineering

G. D. Edwards and A. F. Gilson visited Brazil, Indiana, to discuss with several manufacturers of clay conduit matters concerning proposed inspection survey conferences.

W. A. Shewhart presented a paper entitled *Basis for Analysis of Test Results* at the convention of the American Society for Testing Materials at Atlantic City.

R. M. Moody visited the Gray Telephone Pay Station Company in Hartford, Connecticut, in connection with studies of coin-box telephone stations.

S. H. Anderson and I. W. Whiteside, Philadelphia Field Engineer, visited several telephone offices in the Pennsylvania area to investigate the operation of telephone power equipment.

H. W. Nylund, St. Louis Field Engineer, recently visited Dallas, Oklahoma City, Cushing, and Tulsa, to conduct investigations of telephone equipment.

W. E. Whitworth, Omaha Field Engineer, was in New York to confer with members of the Department regarding field engineering activities.

Apparatus Development

J. R. Townsend presented two papers at the American Society for Testing Materials meeting at Atlantic City. The first, *Physical Properties of Non-Ferrous Metals,* was written jointly by himself, W. A. Straw of Hawthorne, and C. H. Davis of the American Brass Company. It gave further information about the joint specification studies being made by the Bell System and the American Brass Company.

The second paper was written jointly by Mr. Townsend and C. H. Greenall and described fatigue studies of non-ferrous metals in progress at the Laboratories to determine life characteristics of such materials used in telephone apparatus springs.

At this meeting H. A. Anderson presented the annual report of the Committee on Die Cast Metals and Alloys, of which he is Chairman. Over fifty committee members representing principal suppliers and users in the United States are cooperating in investigating die castings, many of which are used in the handset and other telephone apparatus.

Other members of the Department staff who attended the meeting were W. Fondiller, W. J. Shackelton, H. N. Van Deusen, J. M. Wilson, and F. F. Lucas.

H. N. Van Deusen spent the week of July 8 at Hawthorne in conferences on various material problems.

C. H. Greenall attended a conference at Kearny to establish standards for Rockwell hardness tests of sheet metals.

G. W. Folkner has been at Hawthorne working on various manufacturing problems on multiple banks.

D. C. Lloyd has been at Kingston, New York, conducting contact tests on pilot wire regulators for toll lines.

R. M. Pease has returned from a two months' tour of the Southwest and the Pacific Coast where he gave demonstrations in conjunction with S. P. Grace's lectures.

J. G. Ferguson read a paper *Shielding in High Frequency Measurements* at the summer convention of the American Institute of Electrical Engineers at Swampscott. S. J.

Zammataro also attended the meeting.

G. R. LUM visited the Philadelphia Instrument Shop in connection with development of vacuum-tube sockets.

R. V. TERRY and E. W. GENT visited the Olsen Testing Machine Company at Philadelphia to inspect a dynamic balancing machine there. While at Philadelphia they also visited the Bilgrim Machine Company.

PILOTED BY Thomas Durfee the Laboratories plane flew to Hartford where its 400-H.P. Wasp motor was given a general overhauling in the Pratt and Whitney shops. The work required several days to complete after which the plane was returned to its base at Hadley Field. The plane has recently rounded out a full year of service during which its engine-hour record has totaled over 400 hours.

A. B. BAILEY was at Weymouth, Massachusetts, where he supervised the installation of the transmitting equipment for station WEEI, the new 1000-watt broadcast station of the Edison Electric Illuminating Company. He also directed the installation of the 500-watt broadcasting equipment for the Tremont Temple at Boston.

J. C. HERBER is supervising the installation of the five kilowatt broadcasting equipment of Larus and Brothers Company of Richmond, Virginia.

THE CONVERSION of the equipment of the five kilowatt broadcasting station of the Zion Institute and Industries at Zion, Illinois, to crystal control was supervised by O. W. Towner. He also supervised the installation of the one kilowatt broadcasting equipment of the Toledo Broadcasting Company at Toledo.

F. A. HINNERS supervised the installation of the one kilowatt broadcasting equipment of the City of New York.

A PAPER entitled *Telephone Transmission Networks* by T. E. Shea and C. E. Lane was read at the Dallas meeting of the American Institute of Electrical Engineers.

RESEARCH

C. J. DAVISSON has been honored by election to membership of the American Philosophical Society and to fellowship in the American Academy of Arts and Sciences. With F. S. Goucher he attended a dinner given by the Research Corporation at the Century Club in honor of Professors Bergen Davis of Columbia and W. Heisenberg of the University of Leipzig.

AT THE ANNUAL meeting of the American Federation of Organizations for the Hard of Hearing of which Harvey Fletcher is president, a paper, *Audiometer Technique in Public Schools,* was read by J. B. Kelly. E. G. Shower also attended the meeting.

C. H. G. GRAY has returned from abroad where he attended meetings of the *Comité Consultatif International des Communications Téléphoniques á Grande Distance* at Berlin. While abroad he participated in conferences in London and Paris to consider questions concerning the Master Reference System for Telephone Transmission. A paper on this subject written by Mr. Gray and W. H. Martin of the American Telephone and Telegraph Company was presented by the authors at the meeting of the American Institute of Electrical Engineers at Swampscott.

L. H. CAMPBELL and A. E. SCHUH

spent several days at the plant of the Imperial Color Works at Glens Falls, New York, in carrying on investigations of color pigments and their incorporation into paint and lacquer products.

A. N. GRAY visited the Simplex Wire Company at Boston on matters concerning rubber covered wire.

L. E. KROHN, accompanied by D. W. Mathison of the Apparatus Development Department, was at Hawthorne on studies of manufacturing methods of 200-point step-by-step banks.

H. H. LOWRY visited the Jeddo-Highland Coal Company at Jeddo, Pennsylvania, in connection with the investigations which are being made of new sources of coal for use in transmitter carbon.

A. C. WALKER spent several days with the Eastman Kodak Company at Rochester in studying properties and uses of cellulose acetate.

IN COMPANY WITH J. J. Pilliod and A. B. Clark of the American Telephone and Telegraph Company, O. E. Buckley sailed on the S.S. "Nerissa" for St. Johns, Newfoundland. Their trip was made to observe the laying of a short cable which is to be used for a study of interference measurements in the vicinity of Trinity Bay. They were later joined by W. S. Gorton.

J. B. JOHNSON with E. O. Scriven and N. Insley of the Apparatus Development Department attended a conference at the Nela Laboratories at Cleveland on lamps for sound film reproduction.

W. A. MARISON attended the summer convention of the American Institute of Electrical Engineers at Swampscott.

C. W. BORGMANN, J. M. Finch, A. N. Gray, C. L. Hippensteel, J. H. Ingmanson and A. C. Walker attended the American Society for Testing Materials convention at Atlantic City.

A PAPER *Apparent Modulation of Light by Films of Dielectrics on Cathodes of Alkali Metal Photoelectric Cells* was presented by A. R. Olpin at the joint meeting of the American Physical Society and the Pacific division of the American Society for the Advancement of Science held at Berkeley, California. While on the Pacific coast, Mr. Olpin visited the Crocker Research Laboratory in San Francisco and inspected the Farnsworth system of television.

C. F. P. ROSE is in Buenos Aires supervising the installation of transmitting and receiving apparatus preliminary to placing into operation the radio channel from South America to the United States.

PUBLICATION

P. C. JONES addressed a college training group of the Bell Telephone Company of Pennsylvania at Philadelphia. His subject was *The Functions, Accomplishments, and Prospects of Bell Telephone Laboratories.*

The silver trophy, "The Start," awarded to the company scoring most points in the men's competition: Won by the Bell Telephone Laboratories. The large silver cup awarded to the company scoring the most points in the women's competition: Won also by the Bell Telephone Laboratories. Such was the share of prizes garnered by the Laboratories as the last smoke of Starter Murchison's gun cleared away in the second annual track and field meet of the Bell System Athletic League at Erasmus Field, June 22.

Two hundred and thirty men and women representing fourteen branches of the Bell System in the metropolitan district competed for the prizes in the twelve events. The Laboratories men scored a total of twenty-one points and the women sixteen.

The West Street men did not place in the shorter distances which were the 100, 220, and the 440 yard dashes but in the 880 yard event Bonilla broke the tape twenty yards in front of his nearest rival and scored five points for our team. Moffat came in third in this race, adding an additional point to our total.



Bonilla wins the eight-eighty for the Laboratories

In the shot-put Vesely added three points more and Pasanen who had led throughout the trial jumps had to be content with second place in the broad jump. Coincidently enough, he was beaten in the last jump by the same man from the New York Telephone Company, Long Island, who defeated him on the last jump in 1928.

The high jump again was won by New York Telephone Company, Long Island, with Nelson of the Laboratories landing in third place.

After a bad start in the mile relay, our team, by supreme effort, managed to finish in second place.

Again this year the tug-of-war proved to be the feature of the games. In the trial pull, our team, coached and trained by Bill Calmar, defeated New York Telephone, Eastern Manhattan, with ease, but in the finals it was not until the last five seconds of the three minute pull that we were able to take the event from the New York Telephone Company, Long Island. Throughout the entire three minutes the tape see-sawed across the center mark. Considerable interest and rivalry was shown in this event and amidst the greatest excitement ever witnessed at a Bell System meet, Calmar's strong men pulled the tape on their side one-quarter of an inch,

just an instant before the gun was fired announcing the end of the pull. C. T. Boyles, judge for the event, declared the Laboratories the winner.

Last but not least we want to tell about the creditable showing of our women athletes — and there is much to tell. For five years Marie Boman has stood out as the best woman athlete in the Bell System competition, and on June 22 she again demonstrated that she can beat the best that the associated companies have to offer. In the trial heats for the sixty yard dash she had things all her own way, and then won the finals in the exceptionally good time of seven and nine-tenth seconds. Miss Smith, also of the Laboratories, finished second, in eight seconds flat.

Miss O'Neil finished in second place in the basketball throw; this event being won by Miss De Martini of Bronx-Westchester who repeated her victory of last year.

The quarter-mile relay for women was also won by the Laboratories. Miss Boman, running as anchor, demonstrated that she still had considerable speed left after her previous runs and won this event for her team by a fifteen yard lead.

Point — Set — Match

We admit that the English Singles Tournament at Wimbledon is the tennis classic of the year. Nevertheless we can claim that our recently completed Singles Tournament aroused no less keen competition. Fifty-eight men in all took part in the tournament which resulted in Sam Durand being crowned singles champion of the Club.

Many exciting matches were played and numerous upsets took place in the early rounds. K. S. Johnson, who was seeded as Number Two man, was eliminated in the third round by Tolman, and Lamoreaux, Number Four man, was put out in the second round by Langborgh.



Marie O'Neil wins second place in the basketball throw

J. C. Kennelty deserted the golf committee temporarily to serve on the tennis committee and was kind enough to make arrangements for the semi-final matches which were played at the Marine and Field Club at Bath Beach. In the semi-final round Durand defeated Elliott in three straight sets, 6-1, 6-3, 7-5, but it took Entz five sets to eliminate Tolman, who, after losing the first two sets, 6-2 and 6-3, staged a come-back, winning the third and fourth sets, 5-7 and 3-6. The strain, however, was evidently too much and Entz won the fifth, 6-0.

The finals were played on the Notlek Courts, Tuesday evening, June 25, and after four hard-fought sets



Nelson scores in the high jump



Pasanen wins 3 points in the broad jump



New York Tel., Eastern Manhattan—



The winning relay team: Marie Boman, Emily Smith, Katherine Fenton, Marie O'Neil



Marie Boman finishes first in the sixty-yard dash



loses to the Laboratories in a trial heat

Durand was declared the winner. The score of 6-3, 6-4, 4-6 and 6-1 does not tell the true story of the match. Every point of each set was bitterly contested and many times the games went to deuce before game point was scored. Both players were very cautious in the first two sets but opened up in the third. It was in this set that Entz made his bid for victory, winning the set 4-6. After the ten minutes rest period at the end of the third set, Durand came back on the court, cut loose with a brand of tennis that Entz could not handle, and won the fourth set and match.

From the caliber of tennis displayed by our players in this tournament we feel confident of placing a successful eight-man team in outside competition. The Club doubles championship will start on Saturday, September 7. For information regarding entrance in this tournament consult W. Kuhn.

Glee Club

The Laboratories Glee Club assisted in a song recital given by the pupils of Vere Richards before a large audience in Carnegie Hall.

Golf News

On Saturday, June 29, the Laboratories held its first golf tournament with the New York Telephone Company, Manhattan Area. Two eight-man teams competed in this tournament, which was held on course number five of the Salisbury Country Club and resulted in a victory for the Laboratories team by a score of 6½ to 5½. The scoring was based on match play with a point for each match and a point for low ball in each foursome. The results of the matches follow:

Kramer, N.Y.T., defeated Hillier, B.T.L., 3 up.
Groves, N. Y. T. defeated Thorn, B. T. L., 6 up.
Bittner, N. Y. T. defeated Kellogg, B. T. L., 5 up.
Seaman, N. Y. T. defeated Wood, B. T. L., 3 up.
Roberts, B.T.L., defeated LeCluse, N.Y.T., 8 up.
Kidde, B. T. L., defeated Morgan, N. Y. T., 5 up.
Clark, B. T. L. defeated La Voie, N. Y. T., 8 up.
Burwell, B. T. L., defeated Brody, N. Y. T., 8 up.

This match is the first of a number of similar tournaments which will be held with teams from other commercial houses and associated companies in the metropolitan district.

In winning this tournament from the New York Telephone Company, the Laboratories' team is awarded a trophy to be retained for one year.

On Saturday, July 13th, at the Salisbury Country Club, the Laboratories' golf team made a clean sweep of their matches with the golfers of the International Telegraph and Telephone Company. All eight men playing for the Laboratories won their matches and also won the one point allowed for best ball in each foursome, making the final score 12-0.

From the caliber of golf displayed by our team, we feel sure that these men can hold their own with the best from associated companies and commercial houses in the metropolitan district. J. G. Roberts defeated his opponent nine up and eight to play, turning in an eighty-one which was low for the tournament.

The tabulation follows:

W. L. Downing defeated E. Wagenstein 5 up, medal score 87.

E. H. Clark defeated F. C. Shann 4 up, medal score 87.

G. E. Kellogg defeated D. McDonald 5 up; medal score 86.

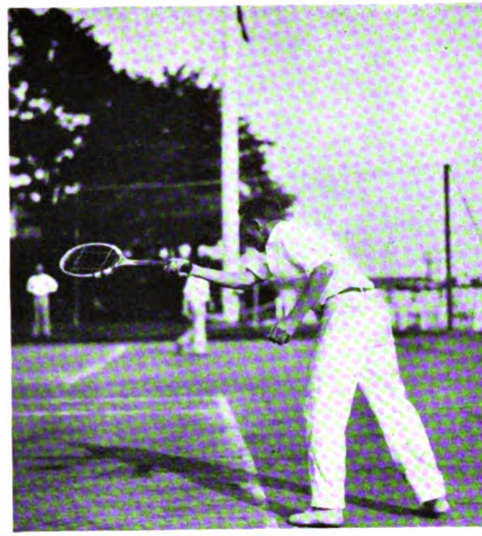
J. Hillier defeated C. Wagenstein 5 up, medal score 90.

H. W. Wood defeated G. H. Gray 5 up, medal score 86.

J. G. Roberts defeated J. Goodrich 9 up, medal score 81.

G. T. Lewis defeated S. Babcock 5 up, medal score 86.

J. C. Kennelty defeated W. J. Brown 5 up, medal score 94.



Elliott, semi-finalist



Tolman, semi-finalist



Durand, winner



Entz, runner-up

Contributors to this Issue

A. A. OSWALD received from Armor Institute of Technology the B.S. degree in 1916 and the E.E. degree in 1927. With the Laboratories since 1916 he has been continuously engaged in its successive radio projects. He took part in the development of long-wave transatlantic telephony, and was at Montauk for the early transmission experiments. During the World War he had charge of the field-testing of airplane-telephones for the Signal Corps, and devised a method of radio-control for airplanes in flight. From 1919 to 1922 he assisted in the development of ship-to-shore communication. Since then he has been concerned with the long-wave and short-wave transoceanic systems.

M. E. FULTZ received the E.E. degree from Pennsylvania State College in 1914. From two years with both the Marconi Wireless Company and the International Radio Company he received wide radio experience, then joined these Laboratories in 1920. He has participated in the ship-to-shore, long-wave (at Rocky Point) and short-wave radio-telephone developments.

E. B. FERRELL received the B.A. degree in 1920, and the following year the B.S. degree in electrical engineering, from Oklahoma University. After three years as instructor in mathematics there, he received the M.A. degree, then came to the Research Department of these Laboratories to work on short-wave radio problems. He has had a large part in the development of the transmitters at Lawrenceville.

E. J. STERBA received the B.E. degree from the University of Iowa in 1920, and joined the Research Department of these Laboratories in the fall of that year. Since 1922 he has been engaged in the development of radio antennas, especially short-wave transmitting antennas of the directive types.

F. A. POLKINGHORN received the B.S. degree in electrical engineering from the University of California in 1922. After two years with the Naval Radio Laboratory at Mare Island, and a year in San Francisco engineering the development and manufacture of vacuum tubes, he joined the Pacific Telephone and Telegraph Company for transmission and plant methods work. Since 1927, when he was transferred to these Laboratories, he has worked on radio transmission and reception.

AFTER three years with the United States Navy, E. Bruce entered Massachusetts Institute of Technology in 1920, and joined the Engineering Staff of the Clapp-Eastham Company in 1922. In 1924 he received the B.S. degree in electrical communications and came to the Research Department of these Laboratories. Mr. Bruce has been principally concerned here with the development of short-wave field-strength measuring equipment and directive receiving-antenna systems.